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NOTES ON THE FLOOD OF MARCH, 1904, IN THE LOWER SUSQUEHANNA RIVER.

By John C. Hoyt* and Robert H. Anderson.

During the last century there have been three notable floods on the Susquehanna River, namely: the floods of March, 1865, June, 1889, and March, 1904. The flood in 1865 was the result of the rapid melting of a large quantity of snow and ice which had accumulated during an especially severe winter, and its amplitude was probably increased by ice gorges. But little information in regard to this flood is available. At the junction of the North and West Branches the river was 2 ft. higher than the flood of June, 1889, and it is safe to say that the elevation of the crest of the two floods was almost the same at most points along the river.

The flood of June, 1889, was caused by the heavy rains of May 30 to June 1, the same which brought about the Johnstown flood in Western Pennsylvania. It probably exceeded any flood which ever occurred on the Susquehanna. Being in the summer months, it was not augmented by ice gorges, and it therefore illustrates the normal effect of high water conditions. The area of greatest rainfall was within the limits of the West Branch, and according to the reports of the Army Engineers, its duration was about 34 hours and an average depth of about 6.6 ins. fell. Under ordinary conditions about 50% of the rainfall in this basin reaches the outlet of the river, and it is probable that under these extraordinary conditions at least 75% of the total fall flowed down the river.

Based upon the discharge measurements which have been made at the Harrisburg and McCall's Ferry gaging stations, it is estimated that at the highest stage of the 1889 flood 593,000 sec.-ft. of water were flowing down the river past Harrisburg, and 671,000 sec.-ft. past McCall's Ferry. These estimates were made by plotting the mean velocities of the various discharge measurements made at these stations as abscissae and the corresponding gage heights as ordinates. Through these points a mean velocity curve was drawn and extended to reach the highest gage heights of the flood, thus giving a curve from which the mean velocity for any stage of the river could be obtained. This velocity times the area of the cross section as defined by the crest of the flood line gives the quantity flowing. The mean velocity thus estimated was at Harrisburg 7.24 ft. per second, and at McCall's Ferry 11.90 ft. per second. The gage heights at the respective places were 27.1 ft. above low water mark of 1804, and 162 ft. above mean sea level. These estimates are somewhat lower than those made by various engineers based on Kutter's formula, which range from 700,000 to 800,000 sec.-ft. A study of the other velocity curves made in this manner show that the results obtained thereby are quite reliable and probably much more so than Kutter's formula determinations.

These results give the maximum discharge at McCall's Ferry about 13% greater than at Harrisburg, which is in accordance with the assumption that the discharge between two points on the same river where the drainage area is similar should increase in proportion to the drainage area. The drainage area at McCall's Ferry is 11.5% greater than at Harrisburg. In May, 1894, the water at McCall's Ferry rose to within 2 or 3 ft. of the flood of 1889.

The recent flood of early March, 1904, was primarily caused in January* by the ice breaking up without enough water behind it to force it through to the bay. Gorges were formed at various points along the river and its branches, which were greatly solidified by the exceptionally cold weather in the following month. When the final break came, these gorges were still further augmented and acted as dams, impounding the large quantity of water which was so destructive to property along the shores.

On March 6 and 7, there were heavy rains all over the drainage area, and, on the morning of March 8, the flood so caused began to break through the various ice barriers. It finally forced the big gorges at Highspire and Bainbridge, wiping out islands and doing much damage in its course. The field of ice at Turkey Hill resisted for some hours until between 1 and 2 P. M., when it in turn gave way and moved to Shank's Ferry. Though it held there but a short time, water and ice were piled 6 ft. over the railroad trackts at Safe Harbor, completely destroying the stone arch railway bridge and leaving the village under 20 ft. of ice. The elevation of the crest of the flood varied in height at different places along its course as compared with the June flood of 1889. At York Furnace it was 3 ft. higher; about a mile above McCall's Ferry it was practically the same; at McCall's Ferry station it was 3 ft. lower, and at the head of Culley's Falls it was again about the same height.

VIEW LOOKING DOWN SUSQUEHANNA RIVER, FROM YORK HAVEN RAILROAD STATION, MARCH 16, 1904.

The flood wave lasted only about 12 hours, and there came down with it a large amount of ice, pieces of which varied in size from 3 to 10 ft. in thickness, as shown by the blocks left on shore. In the lower river, owing to the cross currents, the greater portion of the ice went down on the west side, and on this side many ice walls were left; the channel on the Lancaster side soon cleared itself and but little ice accumulated on that bank. The gorge at Turkey Hill broke about 2 p. m. and at 3:30 p. m. the water reached its maximum height at McCall's Ferry, which was, at the cable station, 160.6 ft. above mean sea level. Within an hour from the time the maximum height was reached, the water had fallen 2 to 3 ft., and by the morning of March 9, it had fallen to 145 ft.

Between Shank's Ferry and the bay no ice gorges were formed, and the ice passed through the channel of the river very rapidly, causing but

*U. S. Geological Survey, Washington, D. C.

*A View of Bridge Spans Carried Away in an Ice Jam on the Upper Susquehanna was shown in Engineering News of Feb. 25, 1904, p. 185.

little damage. Above Shank's Ferry, however, much damage was done by the ice, and the loss of property was great at many points.

The history of nearly all floods has been that, between the Neck and Port Deposit, but little gorging takes place, and that the river rapidly clears itself from ice and seldom rises to such a height as to cause particular damage along its banks. This is interesting to those who contemplate power development in the lower portion of the Susquehanna, as the possible damage from ice has been one of the great objections to such development. The accompanying photographs show the flood and its effect at York Haven and McCall's Ferry.

YORK HAVEN POWER PLANT, LOOKING DOWN STREAM, MARCH 16, 1904.

The cable gaging station, about three-quarters of a mile above McCall's Ferry, offered a good opportunity for determining the amount of water flowing at the maximum stage. At this point two cables are stretched across the river 80 ft. apart, and, at the time of the flood, the sun was in line with these and shining bright enough to cast their shadow on the white ice, thus enabling the determination of the velocity of the ice cakes with a considerable degree of accuracy. The velocity was determined at four different portions of the river, and several individual determinations were made in each portion. The result of this measurement is shown in the table below.

Flood Discharge at Cable Station, McCall's Ferry, Pa., Mar. 8, 1904, 4 p. m. El. W. S. Lancaster Co. side 161.3, York Co. side = 159.8, Mean = 160.6. (a)

Stations.	Surface Velocities ft. per. sec.	Mean Vel. 90% of surface. ft. per sec.	Area. (b) sq. ft.	Discharge. sec.-ft.	Remarks.
−50 − 1 + 25	0	.....	4,710	0	Ice piled along tow-path. No apparent velocity.
1 + 25 − 6 + 25	20	18	23,560	424,000	Velocity obtained by timing ice cakes between cables 80 ft. apart.
6 + 25 − 7 + 25	13.3	12	4,600	55,200	Velocity obtained by timing ice cakes between cables 80 ft. apart.
7 + 25 − 8 + 25	0	.....	4,370	0	Backwater behind Streeper's Island.
8 + 25 − 9 + 75	13.3	12	6,960	83,500	Velocity obtained by timing ice cakes between cables 80 ft. apart.
9 + 75 − 11 + 80	11.4	10.2	6,700	68,300	Velocity obtained by timing ice cakes between cables 80 ft. apart.
11 + 80 − 13 + 20	0	.....	3,600	0	Ice and backwater.
Total	.....	.....	54,500	631,000	

(a) Corresponding G. H. for 1889 flood was about 162, with discharge of 671,000 sec.-ft.
(b) The areas were determined from levels taken by Mr. Anderson during the low water of 1902.

JOHN BURNS AND THE BATTERSEA METROPOLITAN BOROUGH.

(Editorial Correspondence.)

John Burns is well known as one of the leading municipal socialists and labor reform leaders in Great Britain. Battersea, one of the 28 metropolitan boroughs composing London, is his home. The London County Council and the House of Commons are the scene of his official political labors, but his influence is world wide.

Armed with a letter of introduction I approached Mr. Burns one day in the public lobby to the House of Commons. The first sentence which most Englishmen have spoken when I have presented letters of introduction has been "What can I do for you, sir?" Mr. Burns' first words were even more abrupt, being "What do you want of me?" I am glad to be able to add that neither the standard form of greeting, if it can be called that, nor Mr. Burns' question are any indication whatever of the manner—which has always proved courteous and usually most cordial—in which I have been treated after I had made known the object of my visit. On the contrary, this imperative demand seems to be simply the British way of coming immediately to the point, and, oftentimes, of putting one's self wholly at your service. And so it was that Mr. Burns' subsequent treatment of me has been in striking contrast to the brusqueness of his first greeting. He at once invited me to call at his house and gave me access to the visitors' gallery in the House of Commons. When I called on him he not only showed me his large, fine working library* and chatted with me at length about things British and American, but he also took me on an interesting pedestrian excursion through the streets of Battersea, and to various public buildings and undertakings, showing me with great pride the operations of a borough council where workingmen are in the majority. On a later day a hand was waved to me as I was making my way through a busy London street, and I recognized Mr. Burns. He inquired what was my destination, and, on being told, informed me that he was going in the same direction, and would be my guide. We had a long walk together and almost the whole distance he talked of the direct employment of labor, as a substitute for the contract system, that particular topic having been introduced by my informing him that I heard him speak at the meeting of the London County Council, the previous afternoon, on the constitution of the new Works Committee of the council.

Mr. Burns has just been re-elected to the London County Council, on which body he has served since it superseded, with enlarged powers, the old Metropolitan Board of Works. That was in 1889, and out of a total of 118 members, Mr. Burns is one of 14 who were elected to the first council. The Moderates have opposed, among other movements started by the Progressives, the Works Department of the Council, but at the debate mentioned just above they were arguing for representation on the Works Committee, asking for two of the seven members. The Works Department carries out, by direct labor, undertakings not falling within the scope of the regularly organized permanent departments, and its operations have been a bone of contention in and out of the Council. Mr. Burns spoke ably against allowing the Moderates representation on the Works Committee, at least until such a time as they should show sincere repentance for their efforts to wreck the Works Department. His remarks were forceful and were listened to with close attention. When the vote was taken the proposition to put Moderates on the Committee was declared lost. It appears that the labor members of the London County Council have, as a self-denying ordinance, persistently declined representation on the Works Committee. Similarly, some years ago, Mr. Burns was instrumental in excluding men not actually working at their trade from membership in the Amalgamated Association of Engineers, thus cutting himself out of membership in an organization in which he had been very active.

Mr. Burns takes great satisfaction in classing himself among engineers, and in attributing his success in municipal government to the fact that he was trained as an engineer. His parting words to me after our inspection of the public works of Battersea were an injunction to claim for engineering the results of his efforts in municipal affairs. Perhaps I should explain, for the benefit of American readers, that the manufacture of engines, tools, and goods used in the construction, or forming a part of, engineering works is classed in Great Britain as engineering. It was in such work, as I understand it, that John Burns gained the practical knowledge that has been of such benefit to his fellow citizens.

Fortunately for himself and others Mr. Burns has not rested content, as do so many other men who delight in calling themselves practical, with what he has learned in the shop and engine room. His large and varied library, already mentioned, is an evidence of this, and that he uses his books as tools is well attested by his public utterances.

Mr. Burns is a short, rather thick set, but very active man, with a full grey beard, a keen eye, and quick tongue. As we walked about Battersea, everyone, regardless of age, sex, or condition, seemed to know and respect him, and it was evident that this fact gave Mr. Burns great pleasure, as well it might. He instantly detected a mistake made by a borough workman, which necessitated chipping a few inches from a sidewalk flagstone which the latter was laying.

The flagstone, mentioned above, was one of a lot from Yorkshire, and was being laid to replace a tar-concrete sidewalk on a steep hillside. Tar sidewalks, I learned, are to be superseded, as rapidly as their wear and the borough finances will permit, by either natural or artificial stone slabs. The latter will be made from refuse destructor clinker, in a slab machine operated by hydraulic power. Such a machine has recently been installed and, on a second visit to Battersea, I saw it and obtained particulars regarding both it and the refuse destructors.

From the flag laying we went on through a number of streets bordered with workingmen's cottages, known as the Shaftesbury Estate. These houses, which are built in rows, or blocks, with party walls, number about 1,000 and house some 12,000 people. The streets running past them are macadamized and were notably clean, a fact to which Mr. Burns repeatedly called my attention.

Not far from the Shaftesbury Estate we came to a number of blocks of workingmen's dwellings already built or now under construction by the borough in accordance with the widespread movement in England known as municipal housing, or housing of the working classes. The Latchmere Estate, as this development is called, includes 315

*In his home at 108 Lavender Hill, Battersea, London, S. W.

dwellings, which, with grounds and streets, occupy about eight acres of land. Somewhat over three acres additional have been set aside as recreation grounds. The whole eleven acres were originally allotment ground, or land assigned in very small areas and at a very low price, year by year, for cultivation by the working people. These dwellings are two stories high and, to quote from the report for 1903 of Dr. G. F. McCleary, Medical Officer of Health, each dwelling

is self-contained, with its front door opening on the street; there is no common staircase on the Estate. Each dwelling is wired for electric light, provided with blinds,shelves, combined food cupboard and dresser, and patent combined kitchen range, copper (boiler) and bath, and each has a garden at the back, accessible from the upper floor by means of a staircase.

The 315 houses are divided in capacity and rental price as follows, the scullery being additional to the number of rooms in each case and the rentals being per week: 28 5-room houses at 11¼ shillings ($2.80); 70 houses, each containing two tenements of three rooms, at 7½ shillings; 73 houses, each containing two tenements of four rooms, at 10 and 10½ shillings; and one four-roomed house at 10 shillings. The bath tub is in the scullery and the copper boiler is between the kitchen and scullery and accessible from both rooms. The total estimated cost of this improvement, apparently not including land, is about $555,000, which includes an independent water supply from two artesian wells. The plans for the dwellings were based in part on the results of a competition advertised in 1901. The competition brought in 58 designs and besides the three prizes offered four extra ones were added.

The houses are of brick, with window lintels and sills and portico hoods molded from refuse destructor clinker and granite chips, faced with cement. I entered two houses nearing completion and found them surprisingly compact, convenient, and potentially comfortable. Penny-in-the-slot meters were provided for securing light from the municipal electric light plant, and the inevitable tiny, soft-coal grate was in the sitting room and two of the three bedrooms (these being five-room houses).

From the borough dwellings (and, by the way, the London County Council has also provided municipal houses in Battersea). Mr. Burns took me to a unique combination of municipal buildings, the like of which could not be found in America. They comprised a disinfecting station for household goods, which have been infected with contagious disease, a house for sheltering families while their own houses were being disinfected, and a public mortuary and coroners' court room, with numerous accessory offices. Each of the buildings serving the three general purposes named were entirely independent of each other, although having party walls. Formerly, so Mr. Burns informed me, coroners' inquests were held in low public houses, but here everything was arranged in a decent and orderly fashion, and in accordance with good sanitation. I was told at another place in England, now provided with accommodations for inquests similar to those at Battersea, that not long ago a physician had been compelled to make a post mortem examination on a table which, on being cleared, was at once used for the family meal. England is certainly making municipal progress, but just as certainly it has great need of it and has by no means reached an ideal condition. Not that municipal perfection is claimed here; far from it!

From the mortuary we went to the public baths, only a few steps distant, and a little further on we visited the borough electricity works. The swimming baths are not used in winter, but are covered over and the space utilized as a gymnasium and place for games. The baths for cleanliness are kept open the year around. Small fees are charged for the baths and for the winter gymnasium and recreation facilities.

The borough stables are interesting. I found them of solid construction, in fine sanitary condition, provided with electrically-driven feed-cutting machines, and borough horse-shoers close at hand. The borough work horses are noble specimens of their kind; heavy, well fed and groomed, gentle, and apparently deserving of the prizes that they take in the annual competitions. Mr. Burns contrasted the appearance of these horses with that of some which we saw attached to private work wagons, and unquestionably the borough horses looked far superior to the others.

THE NECK ABOVE McCALL'S FERRY AT THE BEGINNING OF THE FLOOD, MARCH 8, 1904.

The borough hall of Battersea is a comfortable building, apparently well designed for its purpose. The borough surveyor, Mr. T. W. A. Hayward, C. E., was out when we called, but I saw him the following day, and he kindly arranged for me to visit the refuse destructor. Mr. Hayward has just succeeded the late J. T. Pilditch, who, through many years, did much good work for Battersea.

At the borough hall I saw one of a number of stations for distributing humanized, sterilized cows' milk for infants. The reports of the Battersea Medical Officer of Health for the years 1902 and 1903 contain interesting descriptions of these stations, their work, and their beneficial effect upon the infant population. The milk is prepared for distribution at a central station, under the control of a trained woman. The station is provided with sterilizing apparatus and the further process of preparing the milk consists in adding water, cream, and milk sugar, to suit the requirements of infants ranging from two weeks to twelve months old, the quantities of the prepared milk and the number of bottles per day being further varied so as to make eight classes of milk supplied.

The prepared milk is supplied daily, at the stations only, in sealed bottles, at the rate of 1½, 1¾, and 2 shillings (35 to 50 cts.) per week, in advance, according to the age of the infant and the stated amount supplied. Printed instructions for the use of the milk are furnished which enjoin that the stoppers shall not be removed until the child is to be fed and that in no case should the milk be emptied into another bottle. At the end of about a year 400 children were being fed on the milk, which was about the capacity of the station for preparing it.

In 1903, Battersea had a recorded death rate of 14.2 per 1,000, compared with 15.8 for the County of London. This figure is based on an estimated mid-year population of 173,422, in accordance with the assumption that the population increased in 1902 and 1903, at the same yearly rate as for the ten years 1891 to 1901. This assumption, Dr. McCleary states in his report, almost certainly results in an overestimated population, but it accords with the other estimates of the Registrar-General and is accepted for purposes of comparison. The death rates per 1,000 for the census years from 1861 to 1901, as given in the report, have decreased as follows: 1861, 25.7; 1871, 26.8; 1881, 18.7; 1891, 17.9; 1901, 16.3. Even if the figures for 1903 have been made to appear unduly low, the general decline in the death rate during the past 40 years is a notable tribute to improved conditions, and reflects great credit upon the municipal administration of the district itself and of the Greater London of which it forms a part.

The foregoing notes on Battersea have been written with John Burns as a central figure, because he has, directly and indirectly, contributed so much to its municipal success; and because it was through his kindness and sacrifice of time that I was enabled to secure the information presented. As we were hurrying up to the House of Commons, that March afternoon, we caught a few glimpses of Battersea Park, one of the best in London, and also of a park of much smaller area —a few acres on the Thames, snatched from commerce and industry and developed at private expense as a breathing place for the people of Battersea, and at the same time as a pleasing memorial to the work of John Burns in behalf of the people.

M. N. B.

Bournemouth, England, April 6, 1904.

FILTER PLANT AND OTHER IMPROVEMENTS FOR THE WATER SUPPLY OF DANVILLE, ILL.

The water-works of the city of Danville, Ill., is owned by the Danville Water Co., and under a new franchise granted by the city in May, 1902, the company was required to carry out a number of improvements. Accordingly, the company has rebuilt its dam, built a mechanical filter plant, increased the pumping capacity, extended the distribution system, and made other improvements. The planning and execution of these improvements was entrusted to Mr. Daniel W. Mead, M. Am. Soc. C. E., Consulting Engineer, of Chicago, and the dam and hydraulic work was under the supervision of Mr. H. M. Ely, Resident Engineer. The work has now been completed about six months. The operation of the works is under the charge of Mr. G. B. Sidelinger, Superintendent of the Danville Water Co.

The supply is taken from the north fork of the Vermilion River at a point about two miles above the city, where a timber dam was built about 1895. The water is of fairly good quality, as far as purity is concerned, and ordinarily it is pretty clear. At times, however, it becomes very muddy and unpleasant in appearance, and the purpose of the filter plant is mainly to remove the suspended matter rather than to remove any large proportion of bacteria; nevertheless, the contract for the filters contains a provision as to reduction of bacteria.

Under the improved system, a 20-in. suction main extends from the intake at the dam to the pumping station, a distance of 110 ft., as shown in the general plan, Fig. 1. When the water is clear it can be pumped directly to the filter plant, but when dirty it is pumped through an 18-in. main 600 ft. long to a basin of 6,000,000 gallons capacity, which was formerly used as a storage reservoir, but now serves as a settling reservoir. From this a 12-in. gravity main, laid some years ago, runs back to the pumping station, and here the water is delivered to the coagulating basins. From these it passes to the filters, and the effluent flows to a 20-in. collecting main from which it passes to the clear water reservoir or storage reservoir. From this a 20-in. main leads to the suction well of the pumps for the distribution service, but connections are also made to enable the water from the collecting main to be delivered direct to the suction well if required. There is a standpipe 3 ft. 6 ins. diameter and 200 ft. high, with a capacity of 14,000 gallons, but this is not now used.

In regard to the gravity flow to and from the filters it may be noted that the floor of the filter room is 7½ ft. above the top of the dam, and the lake or settling basin is about 1 ft. above the

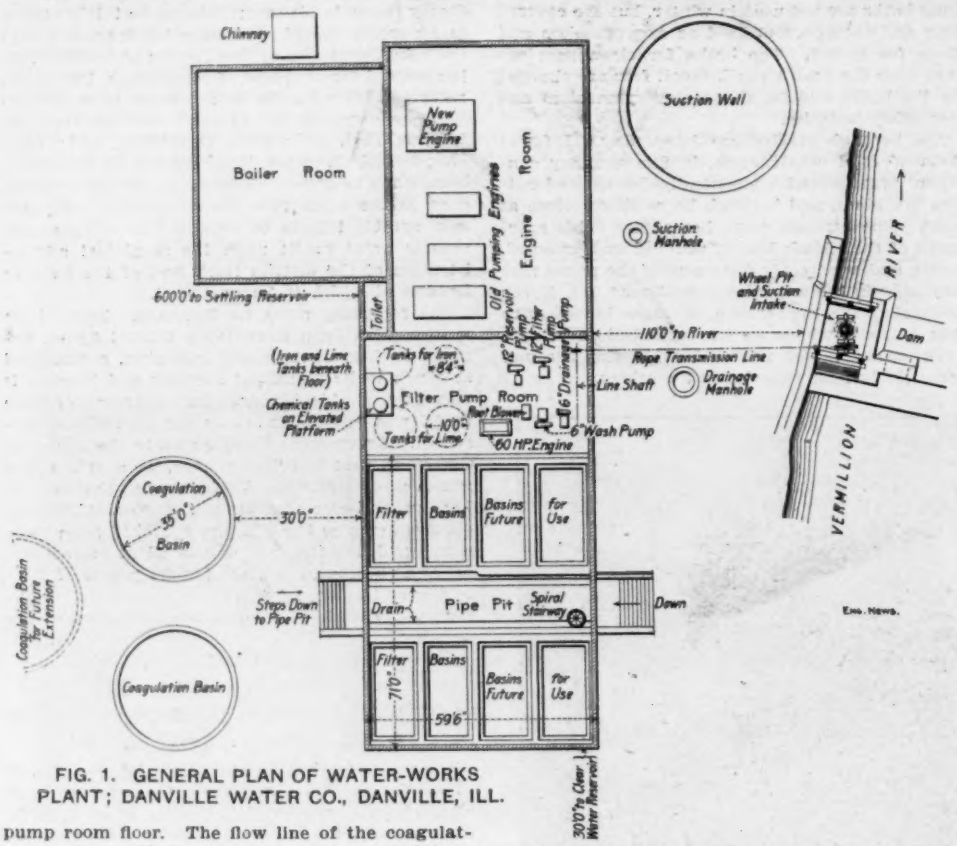


FIG. 1. GENERAL PLAN OF WATER-WORKS PLANT; DANVILLE WATER CO., DANVILLE, ILL.

pump room floor. The flow line of the coagulating tanks is 10 ft. above the floor, and 2½ ft. above the flow line of the filters. The water level of the clear-water reservoir is 12 ft. below the flow line of the filters.

THE NEW CONCRETE DAM.—The timber dam has been replaced with a concrete dam, built against the down-stream face of the former. The new dam is 13 ft. high, with an effective height of 11 ft., and a head of 9 ft. over a 50-HP. turbine operating the machinery of the filter plant. The crest of the dam is capped with timbers carrying standards to support flash boards, as shown in the cross section, Fig. 2. The rear of the crest has a curve of 2 ft. radius, and the down-stream face of the dam is curved to a radius of 8 ft., the width at base being 15 ft. The concrete is composed of 1 part "Owl" Portland cement, 2½ parts sand and 5 parts of 1½-in. crushed limestone. It was mixed in a Smith rotary mixer and made moderately wet. Fig. 3 is a view of the dam under construction, showing the horizontal and vertical joints, the forms just removed, and the ends of the iron rods through the forms.

An interesting feature of this dam is the concrete fishway, Fig. 4, allowing fish to make their way from the lower to the higher level. The fishway is formed in a series of steps of 18 ins. drop, and these steps instead of being horizontal slope alternately in opposite directions, and are separated by plank partitions so as to form a zigzag channel. Across this channel are set inclined baffle boards, staggered as shown in the plan, so as to leave a circuitous passage and break up the current to such an extent as to allow the fish to easily swim against it in going up stream. To protect the fish while passing the fishway, a wooden grating is placed over it and secured with a padlock.

The following particulars of this dam are taken from a paper on "The Danville Water-Works Dam" read at the annual meeting of the Illinois Society of Engineers and Surveyors (at Champaign, Ill., Jan. 20) by Mr. H. M. Ely, Resident Engineer.

The dam is built upon a formation of carboniferous shale, found about 2 ft. below the river bed, and the excavation for foundation was carried about 2 ft into the shale. The old dam was utilized as a cofferdam. The wheel-pit of the new dam was first built, and then the west abutment, while the river flowed through the middle of the dam. The dam was built in sections about 30 ft. long, each section being built in a cofferdam formed by the old dam and piles of sand bags, and kept dry by a centrifugal pump. The dam was built in three horizontal sections. On the foundation section the forms for the second or body section were erected, composed of hard pine flooring nailed to 2 × 8-in. uprights, with ⅝-in. iron rods extending across the form. The form for the upper section had ribs cut to the radius of the convex curve of the crest, and upon these were nailed strips of flooring as the concrete was filled in, until the 6 × 12-in. timbers at the crest were reached. The grooves left by the ribs were afterwards filled with concrete, and the whole face of the dam was given a wash of neat cement. The length of the dam is 236 ft. and the spillway 98 ft.

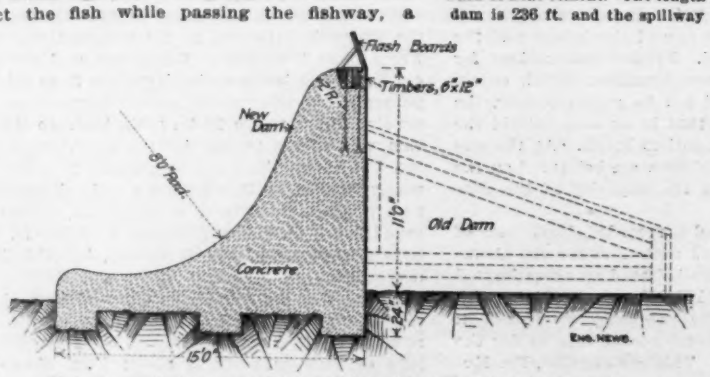


FIG. 2. SECTION OF CONCRETE DAM AT DANVILLE, ILL.

The concrete of the three sections was bonded together in the horizontal joints by 8-in. strips of galvanized iron, 8 to 10 ft. long, set on edge and embedded to a depth of 4 ins. in the concrete, leaving 4 ins. exposed. The next day, the surface of the lower section would be thoroughly cleaned with a wire brush, given a coating of neat cement, and then the new concrete for the upper section was applied, the iron strips being thus embedded in both sections. Further bonding was effected by forming grooves in the top of the concrete of the lower section. The vertical joints between the 30-ft. lengths were made in the same way, except that the strips of iron were embedded in the vertical grooves.

The dam was made of gravel concrete, but stone concrete was used for the wheel-pit. Gravel was obtained from the company's land, but most of it had to be hauled ¾-mile. Stone and cement had to be hauled two miles from the railway, which added 40 cts. per yd. to the cost of the stone, and 8 cts. per barrel to that of the cement. The concrete was made in proportions of 1 to 3 to 6, except that in the foundation a mixture of 1 to 2 to 4 was used. Hand mixed concrete was used for the wheel pit, and machine mixed concrete for all the rest of the work. The average cost of the latter with a wheeling distance of 75 to 300 ft., was $3.90 per cu. yd. The dam was built by day labor. It contains 1,362 cu. yds. of concrete, including the retaining walls, and the average cost per cu. yd. of concrete was $4.35. The average cost per cu. yd. of dam, including excavation, pumping, forms, concrete, etc., was $9.40.

At the wheel-pit, Fig. 5, are two gates, each operated by a rack and pinion, and serving to open or close the head race. About 10 ft. behind these is another pair of similar gates, behind which again is the turbine. Between the two sets of gates is the intake pipe, with an iron rack to catch driftwood. The gates are only lowered in case it is necessary to get access to the turbine or the intake. The power is developed by a 27-in. Victor turbine of 50 HP. at 302 revs. per min. with 8 ft. head. The power is transmitted to a horizontal shaft by bevel gear, and on this shaft are rope pulleys driving pulleys on a shaft 18 ft. above, from which a 1½-in. manila rope transmission extends to the pump room of the filter house.

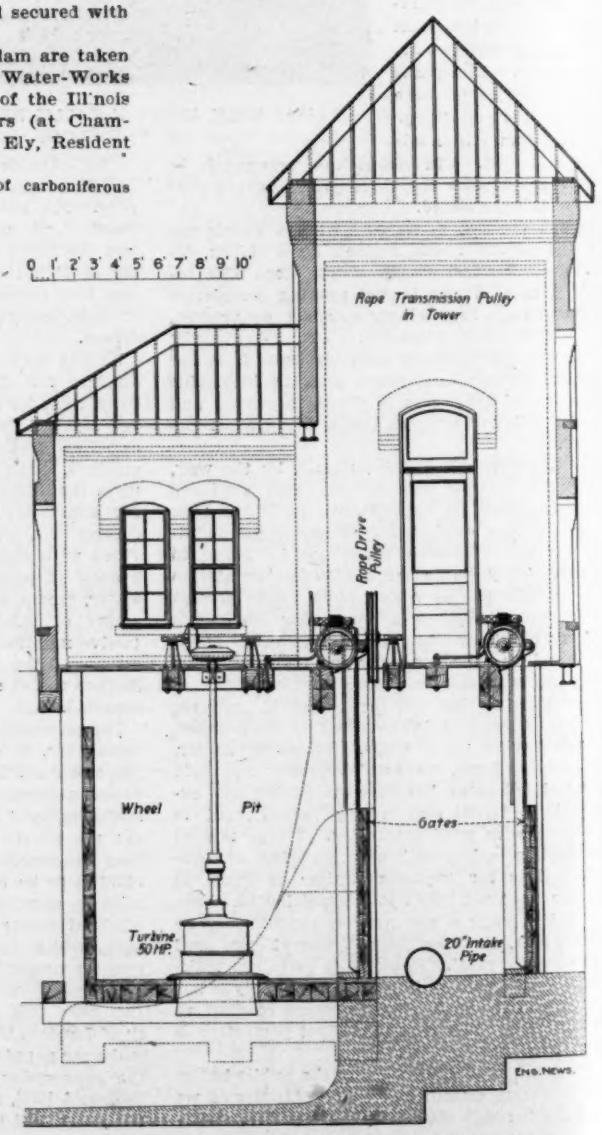


FIG. 5. WHEEL PIT IN DAM AT DANVILLE, ILL.

FILTER PLANT.

The pumping and filtration plants are contained in one building, which is composed of the filter building 58 × 105 ft. and the pump house 48 × 70½ ft., the latter having a wing 47 × 50 ft. for the boiler house. This is shown by the plan, Fig. 1, and the sections, Fig. 6, while Fig. 7 is a view of the plant, with the dam at the right. The buildings are of brick, with concrete foundations, and have triangular steel roof trusses with a plank sheathing covered with vitrified red clay tile. The sheathing is of oiled pine. The filter room has a monitor roof, with ventilating louvres in the sides. The filter room contains not only the filter beds or basins, but also the chemical tanks in which the coagulating solution is prepared; and a sewer connection. All the concrete for the filter beds, coagulating tanks, sedimentation tanks, etc., is composed of 1 part Owl brand Portland cement, 2½ parts sand, and 5 parts crushed limestone, mixed as already described. The coagulant is composed of solutions of lime and sulphate of iron. This solution is prepared in four concrete tanks, two of 8 ft. 4 ins. diameter for the iron and two of 10 ft. diameter for the lime. These tanks are all 10 ft. deep and are in the basement of the filter house. From them the solutions are pumped to two elevated tanks by two belted pumps. From these tanks it is fed by gravity to the main which enters the coagulating basins, the flow of the chemical solution being controlled by a valve with graduated disk. It is specified that the cost of coagulant required to obtain the necessary degree of purification shall not exceed $1.10 per million gallons with water of average turbidity or $1.65 with water of maximum turbidity. The water, after receiving the coagulant, flows to two coagulating or sedimentation basins outside the building. These are concrete tanks sunk in the ground, and covered with conical roofs. Each tank is 35 ft. diameter and 20 ft. deep with a capacity of 125,000 gallons. At the normal rate of flow this allows two hours for sedimentation before the water passes to the filters. Water flows directly through these tanks by gravity to the filters.

Fig. 3. View of Dam Under Construction.

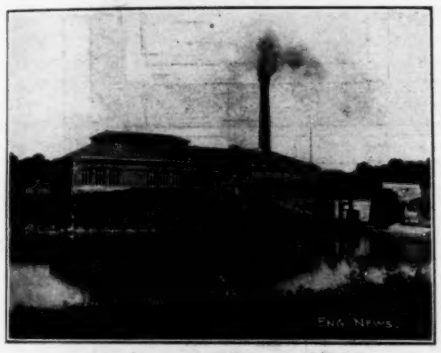
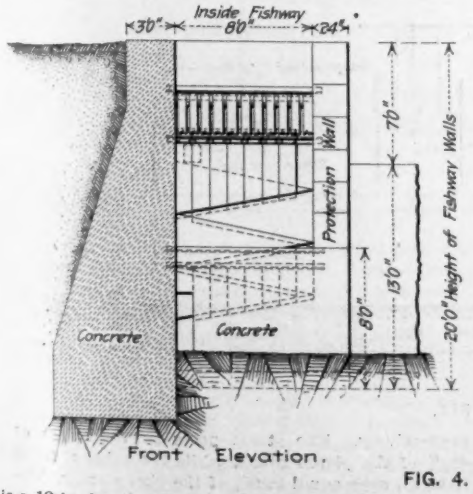


Fig. 7. View of Filter Plant.

Each filter bed consists of a bottom layer of 8 ins. of crushed quartz (covering the system of perforated pipes or manifold); and about 4 ft. of finer washed silica sand, the sand particles being 0.54 mm. in size. The coarser material was furnished by the Wausau Quartz Co., of Wausau, Wis., and the finer material by the Red Wing Filter Sand Co., of Red Wing, Minn. The normal depth of water over the sand is 3 ft., and the discharge is regulated by a Weston effluent regulator.



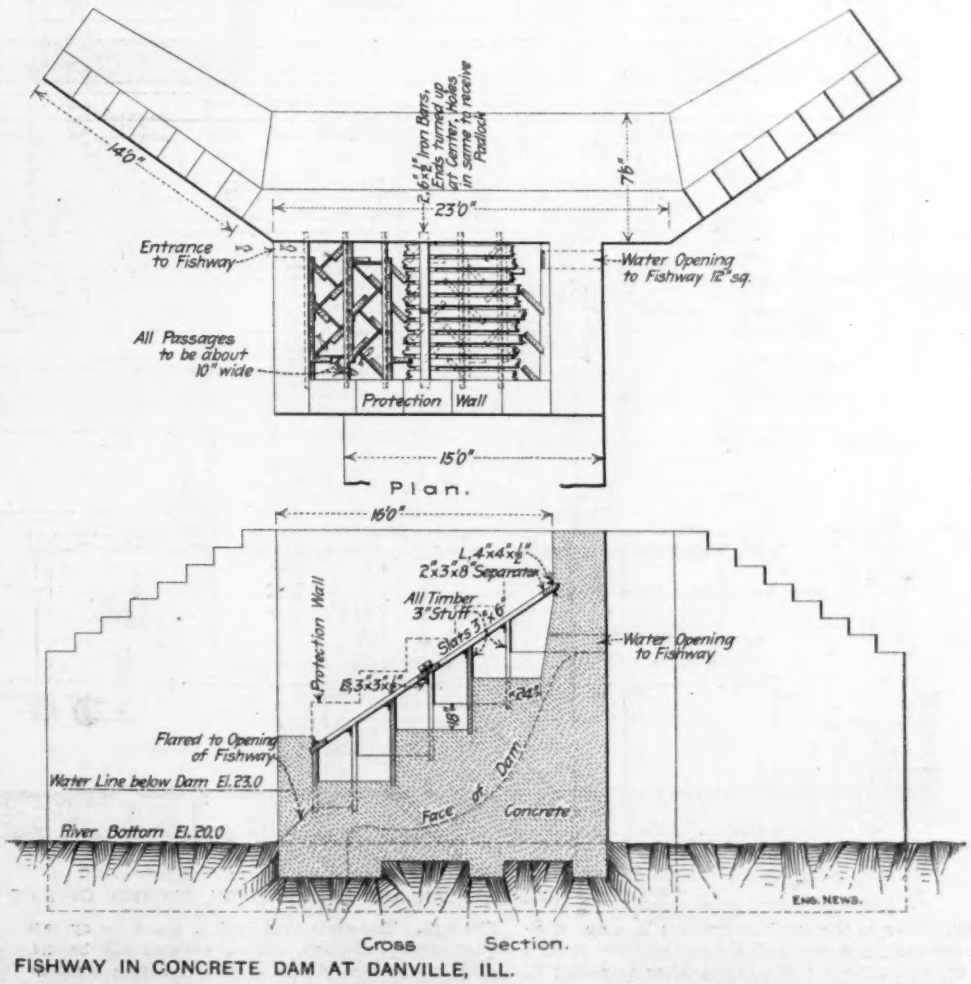


FIG. 4. FISHWAY IN CONCRETE DAM AT DANVILLE, ILL.

the machinery used in connection with the filter plant. There are eight filter basins, in two rows, separated by the pipe chamber, as shown by the interior view, Fig. 8. These basins are of concrete, 27 × 12⅔ ft. at the top and 8 ft. deep, but at the level of the sand (4 ft. below the top) there is a 12-in. bench reducing the size to 25 × 10⅔ ft. On this bench is set an iron trough into which the water from the coagulating basins is delivered, and when the filters are cleaned by a reverse flow the dirty water flows from the filter beds into these troughs, and is drawn off by drain pipes to

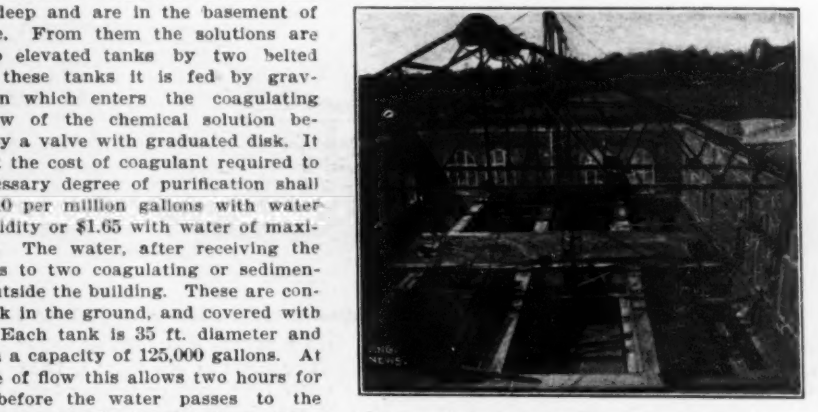


Fig. 8. Interior View of Filter House, Showing Filter Basins and Pipe Chamber.

intervals the sand is agitated by jets of air at a pressure of 3 lbs. per sq. in. The air is supplied by a Root blower, which delivers it to the manifold or strainer system. The dirty water flows off the top of the sand into the trough surrounding the bed, and thence through the wash pipes to the sewers. The capacity of the plant is 6,000,000 gallons per day, at the rate of 125,000,000 gallons per acre per day. At present, however, only four of the beds are equipped for service; each of these has a capacity of 750,000 gallons per day, giving a total daily capacity of 3,000,000 gallons. The plant is guaranteed to reduce the bacteria at least 97% when the water contains over 3,300 bacteria per cu. cm.; but when the raw water contains less than this, the filtered water must not contain more than 100 per cu. cm. The filtered water must show no acid reaction, no trace of coagulant, and no increase in iron or alumina or in alkalinity. Chemical analyses and bacteriological tests are now being made.

At the bottom of the filter bed is the brass manifold for drawing off the filtered water, and also the system of pipes for air washing and water washing. When the sand bed requires cleaning, a reverse current of filtered water is forced up through it by a 6-in. Lawrence centrifugal pump, while at

From the filters the water flows to the clear-water reservoir, Fig. 9, which is of circular form, sunk in the ground, and covered with a flat coni-

cal roof of wood. This roof has radial rafters resting upon circular rows of joists or purlins which are supported by 4-in. pipe posts. The reservoir is 100 ft. diameter at the water line, 80 ft. diameter at the bottom, and 20 ft. deep. It has a storage capacity of 750,000 gallons.

A special feature of the plant is the easy inspection of the filters (which are entirely open), and the convenient arrangement of pipes and valves in the pipe chamber between the two rows of filters. This chamber is 10 ft. wide on the bottom, 12 ft. 6 ins. at the top and 13 ft. 3 ins. deep. The floor over the pipe pit is the operating floor of the filters, and from it the pit is accessible by a winding iron staircase. The pipe pit is also accessible from the outside of the building by a concrete area-way and steps at each end.

The pipe system, shown in Figs. 10 and 11, includes the following: A, 20-in. inlet pipe from the coagulating basins, with 8-in. branch feed pipes, B, discharging into the trough around the filter bed; C, two sets of 8-in. wash pipes, delivering wash water to the strainer system; D, a set of 8-in. rewash pipes for draining the strainer system to the sewer for a few minutes after washing; E, 10-in. drain pipes carrying the dirty water from the filter bed troughs to the sewer; F, 6-in. air pipes above the beds, connected to the manifold system at the bottom by 2-in. vertical pipes; G, 2½-in. steam pipes to carry live steam to the filter beds if desired. The Weston effluent regulators are shown at H, and from these the effluent passes to the 20-in. main, J, leading to the clear-water reservoir.

In the machinery room of the filter house is a main shaft driven by a rope transmission system (two 1½-in. ropes) from the 50-HP. turbine at the dam, or by an Erie automatic engine of 60-HP., in the machinery room. To this shaft are belted the following machines, which, of course, are not all operated at one time: 1, 12-in. pump drawing water from river or settling basin and delivering to coagulating basin through a 16-in. pipe; 2, 12-in. pump drawing water from the river and delivering to the settling basin; 3, 6-in. wash-pump; 4, 6-in. drainage pump; 5, Root blower. All the pumps are of the centrifugal type.

The contract for the buildings, filters, coagulating basins, reservoirs, etc., was awarded to W. W. Davies & Co., of Louisville, Ky., and the strainer and pipe system of the filters was put in by the New York Continental Jewell Filtration Co., of Chicago. The estimated cost of the filter system (including buildings, filters, coagulating basins, clear-water reservoir, and the operating machinery), is $75,000 or $12,500 per million gallons for the total capacity of the plant.

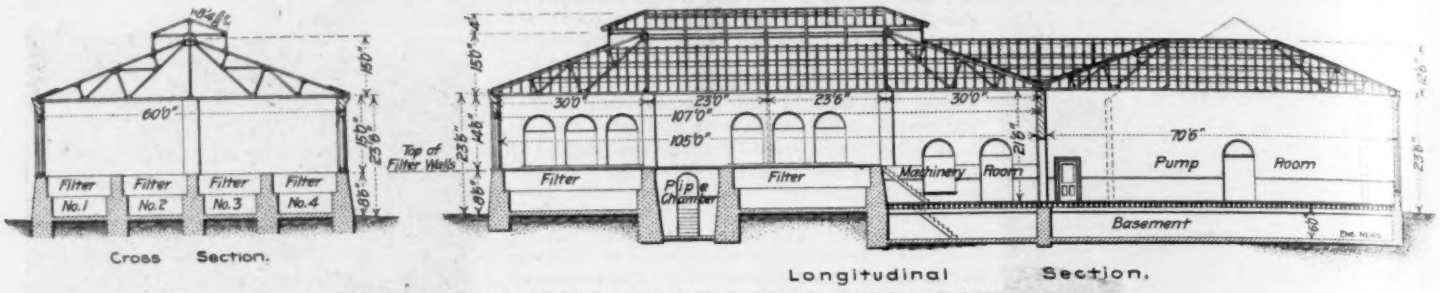


FIG. 6. SECTIONS OF FILTERING AND PUMPING STATION AT DANVILLE, ILL.

NEW PUMPING ENGINE.

The new pumping engine is of the high-duty, cross-compound condensing, horizontal type, with a daily capacity of 5,000,000 gallons, and is designed for a domestic pressure of 95 lbs. and a fire pressure of 125 lbs., with a steam pressure of 135 to 150 lbs. This was built by the Snow Steam Pump Co., of Buffalo, N. Y. There are also a Dean pump and two Blake pumps of the duplex, direct-acting type, and of 3,000,000, 2,000,000 and 1,500,000 gallons daily capacity. Steam is furnished by two return tubular boilers of 125 HP. each, and a new Scotch marine boiler of 150 HP., all working at 150 lbs. pressure.

The new Snow engine has a 17-in. high-pressure cylinder, 36-in. low pressure cylinder, and two 12½-in. double-acting outside center packed plungers, with a common stroke of 36 ins. The piston speed at rated capacity is 280 ft. (or about 46⅔ revolutions) per minute. The steam cylinders are steam jacketed on the barrels and heads, the width of jacket space for the barrels being 1½ ins. on the high pressure and 2 ins. on the low pressure cylinder. The clearance is 2¼% and 2¾% for the high and low pressure cylinders respectively. The steam ports have an area of 4½% of the piston areas, while the exhaust ports have an area equal to 6% of the piston areas. The steam and exhaust valves are fitted in chests on the ends of the cylinders and as near to the bore as possible. Their diameters are 4 ins. for the high pressure and 7 ins. for the low pressure cylinders. The valve gear is of the Corliss type, with

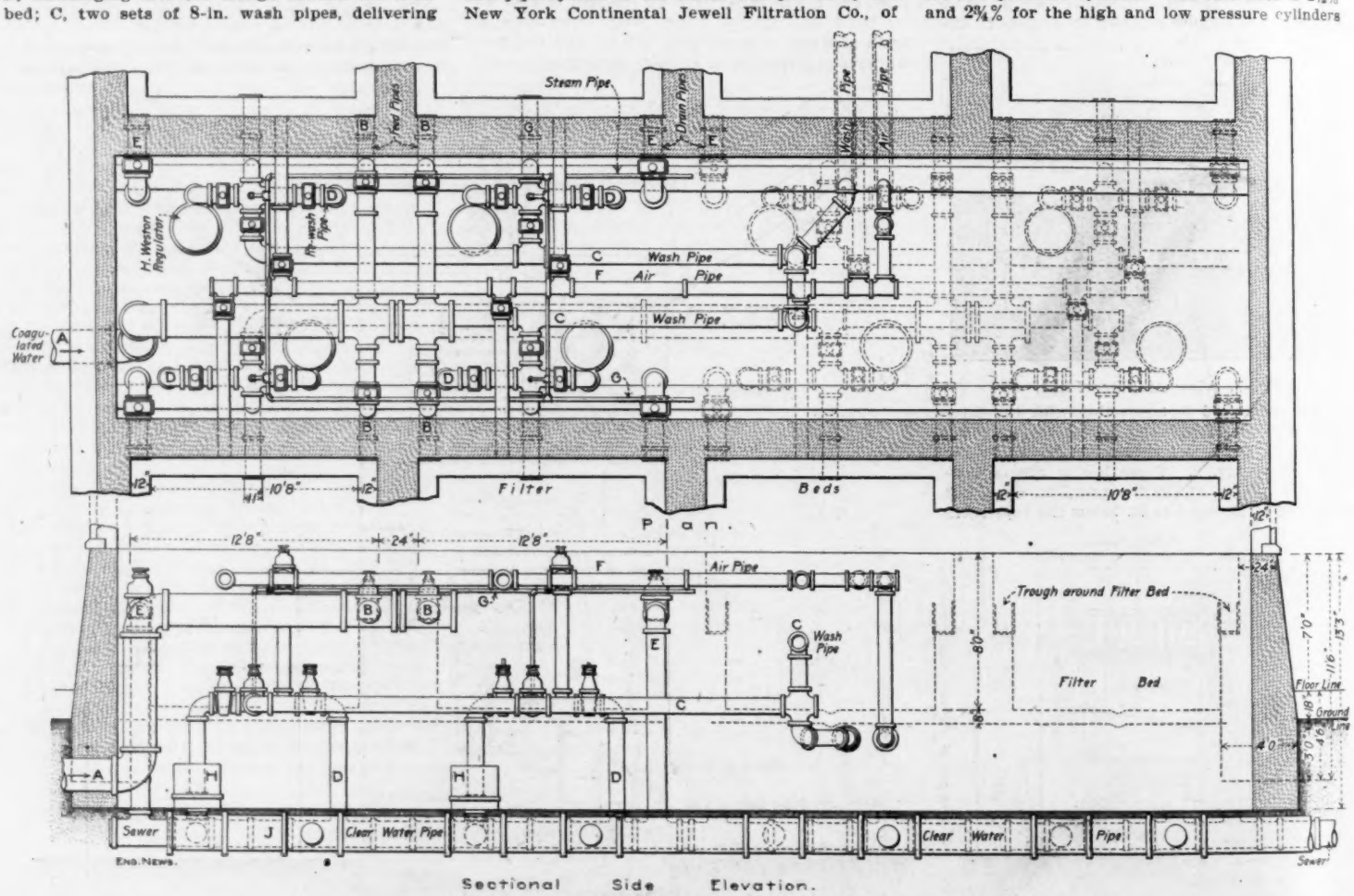


FIG. 10. PLAN AND LONGITUDINAL SECTION OF PIPE PIT.

wide range of cut-off, and the valves of each cylinder are operated from a single eccentric and wrist plate. The vacuum pots are of the double chamber type, with the vacuum chamber below and the compressor chamber above. They are 4 ins. diameter for the high pressure and 5 ins. for the low pressure cylinder. The main shaft is of open hearth forged steel 12 ins. diameter, with main journals 9 × 18 ins., and crank fits 8⅞ × 7 ins. The connecting rods are 7 ft. 6 ins. long, c. to c. There is a 9-ton flywheel, 12 ft. 3 ins. diameter.

The pistons are of the bull-ring and follower type, 7 and 10 ins. wide on the face, and having the bull-ring adjustable to the center of the piston rod by screws, when the piston wears out of center. Each piston has a cast-iron packing ring expanded by springs. The engine has a pressure regulator which will control the point of cut-off in the high pressure cylinder to maintain (with not more than 2 lbs. variation) a constant water pressure. This regulator may be adjusted to either domestic or fire pressure, and it has a safety device to shut off steam in case of unsafe speed.

The receiver contains brass re-heating tubes, of the inner and outer tube type, giving forced circulation. Its volume is four times that of the high pressure cylinder. The surface condenser has about 500 sq. ft. of brass tube surface. There is a vacuum pump driven from an extension of the low-pressure main crosshead wrist pin, and a boiler feed pump driven from the vacuum pump shafting. A jacket pump returns the jacket condensation to the boilers. A 4-in. Stratton steam generator is placed on the 4-in. main steam pipe, and a Warren-Webster oil separator on the 9-in. low pressure exhaust.

The pump cylinders have valves of rubber disks 3¾ ins. diameter with a metal plate between the valve and spring. The area through the delivery valves and suction valves is about 180% of the area of the plunger. Four air chambers of 7 cu. ft. capacity are formed in the force chambers over the pump cylinders, and on the suction pipe is an air chamber of 35 cu. ft. capacity.

Efficiency tests of this engine have shown very satisfactory results. Its guaranteed duty was 130,000,000 ft.-lbs. per 1,000 lbs. of dry steam when run at 5,000,000 gallons capacity (12 hours test), or 120,000,000 ft.-lbs., when run at 2,500,000 gallons capacity. It was first tested at half capacity for a run of seven hours. The average duty at half speed was 126,457,600 ft.-lbs. for 1,000 lbs. of dry steam. A second test was made with a run of six hours at a rate of about 4,500,000 gallons per day, and the average duty was found to be 131,394,000 ft.-lbs.

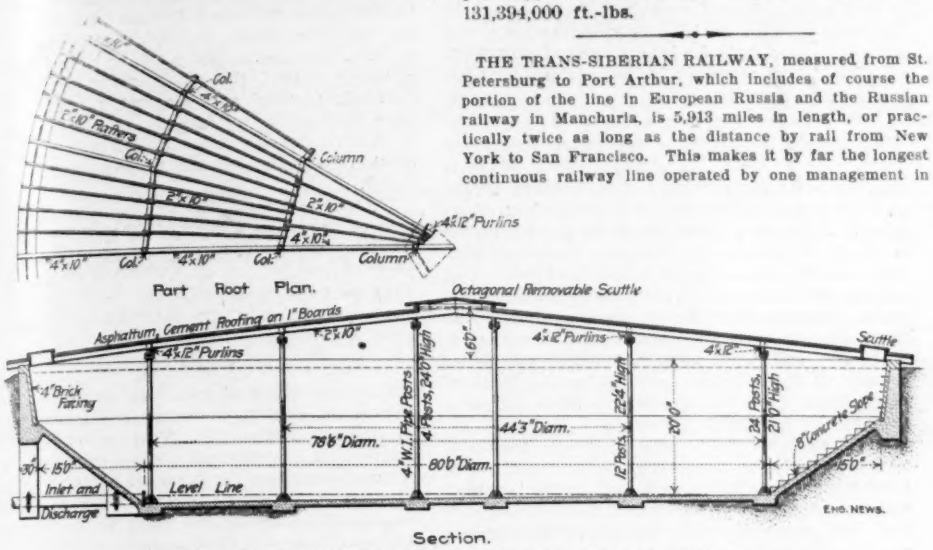


FIG. 9. CLEAR WATER RESERVOIR FOR DANVILLE WATER CO.

THE TRANS-SIBERIAN RAILWAY, measured from St. Petersburg to Port Arthur, which includes of course the portion of the line in European Russia and the Russian railway in Manchuria, is 5,913 miles in length, or practically twice as long as the distance by rail from New York to San Francisco. This makes it by far the longest continuous railway line operated by one management in the world. The next place would probably be claimed by the Canadian Pacific transcontinental line with a total length of 3,387 miles, from St. John, N. B., to Vancouver.

THE MOST SERIOUS RAILWAY ACCIDENT of the week was a derailment on the Mexican Central Ry. on April 19 near Zacatecas, Mex., in which eight persons are said to have been killed.

A GOOD TRESTLE FLOOR averted a disastrous accident on the St. Louis & San Francisco R. R., near Amory, Miss., on April 4. A train was derailed on a trestle while running at the rate of about 45 miles an hour. The whole train traversed the entire length of the trestle after derailment, and upon reaching solid ground the engine, baggage car, express car, and one passenger coach tumbled down an embankment. The engine turned completely over and its smokestack was buried in the ground. The engineer and train crew escaped unhurt and only four or five of the large number of passengers were injured, none fatally.

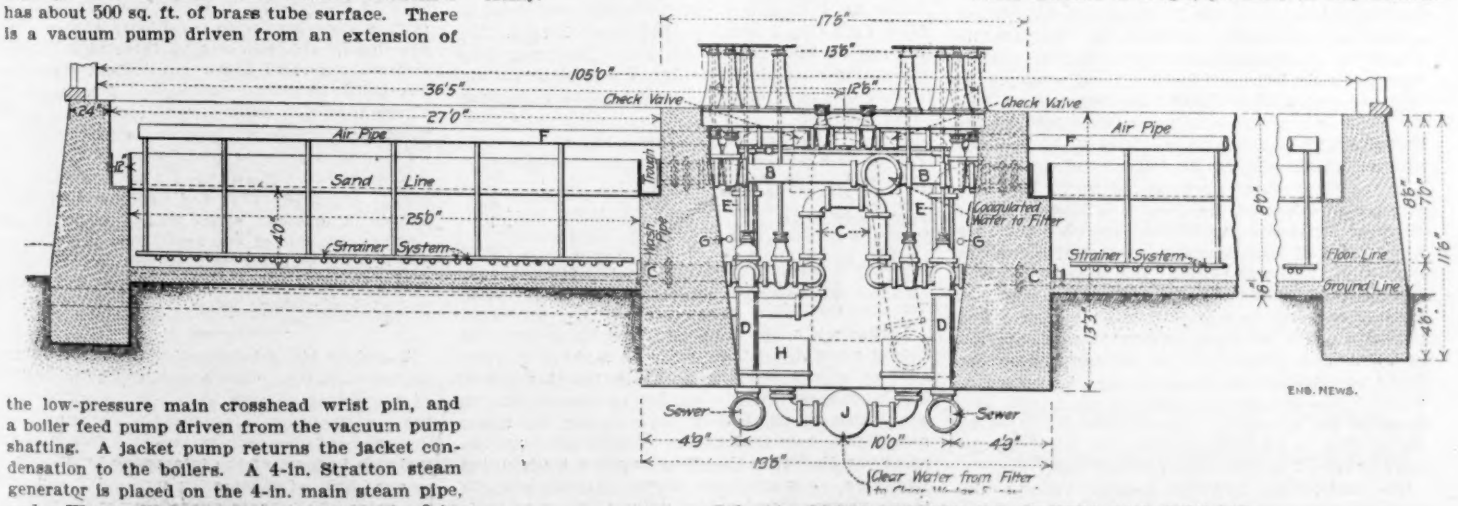


FIG. 11. CROSS-SECTION OF FILTERS AND PIPE PIT.

RAILROAD ACCIDENTS in the United States for the quarter ending Dec. 31, 1903, are reported as follows by the Interstate Commerce Commission:

There were 147 passengers and 299 employees killed, and 1,148 passengers and 2,030 employees injured during this quarter as a result of collisions and derailments of trains and engines. Other accidents to passengers and employees not the result of train accidents bring the total number of casualties up to 14,485, being 175 passengers and 991 employees killed, and 1,937 passengers and 11,382 employees injured, a decrease of 702 as compared with the preceding quarter.

The total number of collisions and derailments was 3,011 (1,832 collisions and 1,179 derailments), of which 287 collisions and 119 derailments affected passenger trains. The damage to cars, engines and roadway by these accidents amounted to $2,527,000, a decrease of $57,348, from the quarter preceding.

While there is a decrease of 52 in the total number of collisions and derailments reported for this quarter, there is an increase of 166 persons killed in train accidents over those reported for the quarter ending Sept. 30. A single derailment resulted in the death of 65 persons, and four disastrous collisions resulted in the death of 99 persons.

The total number of employees killed in coupling and uncoupling cars was 78, being an increase of 8 over the number reported in the preceding three months.

LIGHT AND FIRE PROTECTION can now be established more readily in towns in Iowa, as the State legislature has just passed a law doubling the amount that can be levied for these purposes. In Iowa, the taxes are assessed on one-fourth of the actual value of property, and the old law allowed 5 mills for water supply and 5 mills for street lighting. The new law allows 10 mills for each.

AN EXHIBITION OF FIRE EXTINGUISHING and safety devices will be held at Budapest, Hungary, in August of this year. The "International Union for Protection Against Fire," meets in Budapest during August 17 to 21, and all governments have been invited to send delegates. The exhibition, which will be held during the meeting of this congress, is under the management of the Hungarian Union for Protection Against Fire. A program of the congress and a circular of the exhibition are on file in the Department of State, Washington, D. C.

THE SIMPLON TUNNEL EXHIBITION which was planned to be held in Milan, Italy, in 1905, has been postponed until 1906. The work of preparation will not be delayed on this account. It will be remembered that this exhibition is to be devoted mainly to transportation, with a separate section of Fine Arts. The former section is international, while the latter is restricted to Italy.

MARYLAND HAS MADE A GOOD ROADS APPROpriation amounting to $200,000, thus adding one more State to those lending State aid to the rural districts in road building.

STATISTICS OF THE COST OF ROAD BUILDING are being gathered by Martin Dodge, Director of the Office of Public Roads Inquiries, Washington, D. C. The following letter of inquiry has been prepared:

There is a general demand from all parts of the country for practical information regarding the latest and best methods of road construction and the cost of roads in each section of the United States. In order to meet this demand it is deemed advisable to secure concise and specific information from public road officials, engineers, and road builders throughout the country in reference to roads which have been actually built by them or under their direction. You will, therefore, confer a great favor upon the Department and upon all those who are interested in securing better roads, by preparing brief statements, separate and distinct, regarding each of the best specimens of typical roads built by you or under your direction. An outline of the information desired is as follows:

(1) Location and name of road; (2) Character of construction; (3) Source of material and distance hauled; (4) Kind, width, and depth of material; (5) Kind and weight of roller; (6) Length of finished road; (7) Cost of finished road, exclusive of bridges, per mile; (8) Any additional practical information pertinent to the subject which you desire to submit.

As this information is desired for publication, photographs, cross-sections, or other illustrations may be used to advantage.

This investigation has been placed under the immediate charge of M. O. Eldridge, the Assistant Director, with whom you are requested to correspond directly. If you are not a public road official, road builder, or engineer and cannot supply the information desired, will you kindly refer this communication to some one who has had charge of road work. If you are acquainted with more than one person who can supply such information, please send their names and addresses to this office.

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In requesting change of mailing address, state BOTH old and new address; notice of change should reach us by Tuesday to be effective for the issue of the current week. The number on the address label of each paper indicates when subscription expires, the last figure indicating the year and the one or two preceding figures the week of that year; for instance, the number 325 means that subscription is paid to the 32d week (that is the issue of Aug. 10) of the year 1905; the change of these figures is the only receipt, unless one is sent by special request.

ADVERTISING RATES: 20 cents a line. "Want" and "For Sale" notices, special rates, see pages 26-27. New copy for standing advertisements should be received ten days in advance of publication; new advertisements, Monday morning. The pages containing "Want" advertisements are held open until Tuesday, and those with "Proposal" and "For Sale" advertisements until Wednesday at 11 a. m.

Our readers will pardon us, we are sure, for taking space briefly to record here the passing of another mile-stone in the history of this journal, the present month being the 30th anniversary of the founding of Engineering News. Five years ago, on reaching the quarter-centennial mark, we gave, in our issue of April 13, 1899, a brief summary of the early history of this journal, which was founded in April, 1874, by Mr. Geo. H. Frost, who still continues its active head.

Without taking space to repeat the story of the development of the paper then given, we may state that it was originally started as a modest little monthly journal, which was published at Chicago, April 15, 1874, under the name of "The Engineer and Surveyor." This was changed in the following issue to "The Engineer, Architect and Surveyor," and again changed to "Engineering News" at the beginning of 1875. A year later it was altered from a monthly to a weekly. In 1879 the publication offices were removed to New York, being located for 18 years, until 1897, in the Tribune Building, and since that date at their present location in the St. Paul Building.

At the time of our previous review in 1899, the country was just at the close of a long period of business depression, which had retarded the rate of progress of this journal as it had of industries generally, although there was nevertheless a steady and considerable gain, year by year, in subscribers and in advertising patronage. The past five years, however, have witnessed a period of abounding prosperity, of which Engineering News has enjoyed its full share, and by reason of which it has been able to improve the quality and increase the quantity of the matter presented to its readers to an extent which we could hardly have ventured to hope for five years ago.

Our prosperity, however, merely reflects the prosperity and growth which has attended the engineering profession, which it is our chief aim and purposes at all times and in all ways worthily to represent. The reader who makes a comparison between his Engineering News of to-day and that of five or ten or fifteen years ago will be not far wrong if he takes the two journals as an index of the relative size and importance of the engineering profession at the two dates. And the comparison may extend to the character of the contents as well as to such externals as the number of pages and the figures of circulation. If Engineering News of to-day contains, as we believe it does, articles of more direct usefulness and value to the working engineer than the journal of a dozen years ago, that fact is closely related to the other fact that higher standards prevail in engineering work; that scientific method is everywhere replacing rule of thumb; that the trained and educated engineer is displacing the man of smaller capabilities in executive positions as well as in technical work; and finally, that the engineer in every position appreciates more and more the opportunity for interchange of experience with his fellow members in the profession which this journal supplies.

The article in this issue describing the recent destructive floods in the Susquehanna River is worth more than passing notice because of the unusual circumstances which brought about these floods. A January thaw broke up the ice in the river at a time when it was much harder than at the usual break-up in the spring, and instead of running freely, it piled up in heavy gorges. These were solidified and a new coating of ice was formed on the river during the severe weather of February, and when the snow on the upper courses of the river was melted by the rains of early March, the swollen waters were dammed back by the January ice jams.

While such a combination of circumstances is unusual, it is by no means unprecedented on northern rivers, and the fact that an ice jam may raise the water level of a stream far above its normal high-water mark is one which an engineer should always bear in mind. Of course, in many cases it will not be feasible to locate tracks, bridges, culverts, etc., above the reach of possible highest water, and it may be true economy to run the risk of inundation and consequent damage once in ten or twenty or forty years. In other cases, however, a little study of topography will often reveal where ice jams in a stream will naturally form and what measures will be necessary to guard against the back water from them.

A question very frequently asked is: On what basis should an engineer make his charges for professional services? Practice in this respect varies between very wide limits; but in general the public is not yet educated to the idea of paying an engineer a percentage of the cost of the work under his charge and for which he is responsible, which is the common practice in architectural work.

With special interest, therefore, we notice on the letter head of a firm of consulting engineers in New York City a definite schedule of charges. We have never before seen such a schedule printed by an engineer on his stationery, and feeling certain that it will be of interest to our readers we reprint it as follows:

SCHEDULE OF CHARGES.

Full professional services, including active superintendence and management	10%
Full professional services, including general supervision	5%
Preliminary study	1%
Preliminary study, general drawings and specifications	2½%
Preliminary study, detailed drawings and specifications	3½%

Commissions computed upon entire cost of the work.
Traveling expenses to be paid by client.

Perhaps if more engineers made a practice of boldly advertising their scale of charges in some such manner it would tend to raise the standing of the profession. People are apt to value things in proportion to what they have to pay for them; and if they buy engineering services at about the same per diem rate that they pay to a trade-union workman, they are quite likely to underestimate the importance and actual value to them of their engineer's work.

Perhaps there may be some, even among the readers of Engineering News, who will have some doubt whether the services of an engineer are worth ten per cent. of the cost of a piece of work; or, in other words, whether it is not cheaper in many cases to "muddle through" with a job, as the English say, than to pay one dollar out of every ten spent to have the work done under direction of an engineer who understands his business.

We shall not take space to discuss this question in detail; instead, we merely wish to present a statement that has come to our notice since the note above was in type. The statement is to the effect that a certain city in New York State has expended at least $1,000,000 on unnecessary sewer construction. This has come about through the pursuance of the very common policy of building the sewer system in a hit or miss fashion, extending here and there to meet local requirements without any systematic planning of the work as a whole. Had the whole sewer system been definitely planned at the outset, extensions could have been made from year to year with reference to the final results, and a considerable percentage of the entire cost of the work could have been saved.

We take this merely as an illustration. What is true of sewerage is true of other things in engineering work. The difference between well-planned and ill-planned work is often the difference between prosperity and bankruptcy. The engineer who does the planning well earns the compensation he receives.

The reclamation of coast sand dunes by forestation is the subject of an interesting report by U. S. Consul Albion W. Tourgee of Bordeaux, France. A century ago, a great tract of southern France, extending for 100 miles along the shore of the Bay of Biscay and inland for 50 to 100 miles was a barren desert, due solely to the advance of the great sand dunes, carried forward by the winds from the Atlantic. Formerly the land was occupied by a vast pine forest, not dissimiliar, probably, to the pine forests that line the South Atlantic coast of the United States. This forest was cut off for timber and naval stores in early historic times and fires following burned up the soil and left the sand beneath exposed to the wind. In this way the sand dunes were formed and moved steadily forward year after year until an enormous area of the fertile plains of Southern France had been converted into a desert.

In the year 1801, a resident of the region named Bremontier conceived the idea of planting the "pin maritime," a European species of pine which flourishes along the sea coast, to reclaim the lands. The project was brought before Napoleon and was energetically carried forward by him. To-day this great region is covered with a pine forest which produces lumber, resin, turpentine, railway ties, telegraph poles, etc., in such abundance that France not only supplies her home demands, but exports mine props to Wales and naval stores of certain high grades to the United States. There are nearly 700,000 acres of these pine forests in France, one-third under government control and two-thirds in private ownership. Mr. Tourgee declares that this work of land reclamation is "the most remarkable achievement ever wrought by human agency in the modification of natural conditions of soil and climate for the benefit of mankind. He urges that the experience of France should be a lesson to the United States and that the reclamation of the sand dune regions which are already causing serious loss and damage on many parts of the Atlantic and Pacific coasts, be undertaken without delay.

A curious bit of information comes to us from a correspondent who shuns publicity to the extreme of not telling us who he is. While ordinarily we pay no attention to anonymous communications, the present letter may be excepted from this general rule because of the interesting light it throws on one phase of engineering work. We have verified some of the facts alleged in the letter, and if any misstatements be found in it we ask that they be brought to our attention. The letter in full follows:

Referring to your statement of Dec. 10 that "Specifications are, for the most part, copied with little thought from other specifications," I beg to call your attention to the following amusing facts: The first edition of the Pencoyd Specifications for Railroad Bridges, of 1888, contained a misprint, in that it stated that pins over 7 ins. diameter should be forged with a *steel hammer* (instead correctly "steam hammer"). This error remained in the

24 edition of the same specifications, and can be at present found in the specifications of the American Bridge Co. for Railroad Bridges, 1900 (clause 101), the same company's Specifications for Highway Bridges, 1901 (clause 111), the specifications of the Atchison, Topeka & Santa Fe Ry., 1902 (clause 109), the specifications of the Chesapeake & Ohio Ry., 1902 (clause 66), and in the specifications for the Monongahela Bridge (cantilever) by Messrs. Boller & Hodge, 1901 (clause 23). In the last-mentioned case it is still more interesting, as the wording of the clause has been changed without changing, however, "steel" to "steam." Yours truly, Engineer.

The facts alleged in the above make out a pretty good case of semi-hypnotic suggestion. They also imply that there is the fullest justification for the labor that in recent years has been put upon the improvement of specifications: the efforts of the American Society for Testing Materials, the articles and comments in Engineering News on the subject, and (most important) the work of numerous consulting and constructing engineers in originating, studying and amending specifications of all kinds. One can hardly ask for clearer evidence of the need for such work than the spread and continuance of an error in that class of specification which we generally hold to be the most exact and thorough—specifications for steel structures.

An interesting problem in mechanical engineering is brought to our attention by the receipt of a circular from a well-known manufacturer of compressed air machinery. We may state the problem in its most general aspect about as follows: Given a supply of compressed air at a high pressure. Wanted a supply of compressed air at a lower pressure. What is the most economical and efficient manner to obtain the latter from the former?

Stated more specifically, the high pressure air will be at a pressure of 100 lbs. per sq. in., more or less, such as is commonly used for operating pneumatic riveters and similar tools. The low pressure air should be at a pressure of a few ounces, and is required to blow a portable rivet-heating forge. Evidently there are two ways of solving the problem. We may either use a tiny jet of compressed air in an ejector to obtain a large volume of low pressure air for the forge, or we may let the jet of air strike the blades of a fan which, being thus caused to revolve, will blow the forge. The question is, which of these two methods ought to be the more efficient, theoretically?

On a cursory view, the ejector method would seem to have everything in its favor, for there are no moving parts, and no loss by friction or inefficiency of the fan. If we assume an ejector nozzle properly proportioned, it is difficult to see where the kinetic energy of the moving high-pressure air can go to except to set in motion the adjacent air.

But now come the aforesaid manufacturers of pneumatic machinery, whose reputation is such as to justly entitle them to rank among the foremost authorities in this field, and offer a device working on the contrary principle. Their apparatus consists of a portable forge with a fan blower, but instead of a smudgy-faced boy to drive the fan, a small jet of compressed air, striking against the blades of the fan, does the trick and leaves the rivet boy free to handle his tongs and toss the rivets where they are needed.

Now we can readily understand that such a forge might have a practical advantage over a forge with a compressed air ejector blower, in that the fan is always ready to be operated by hand in case compressed air is not available; but the makers of the forge, the Ingersoll-Sergeant Drill Co., make a distinct claim of superior efficiency for the device. They say:

> It only requires from 5 to 7 cu. ft. of air per minute to operate this blower, as compared with 25 to 30 cu. ft. of air used by air forge using compressed air direct on fire.

We can readily understand that if a jet of 70 lbs. compressed air were used direct on a forge, it would be uneconomical; but the above comparison ought in fairness to be made with a properly designed ejector.

Is it actually the case that a jet of air, or of steam for that matter, will work more effectively in moving other air if it drives a fan than if it acts directly by entraining the air in its motion?

We trust that some of our readers may be able to furnish an authoritative answer to this question, and if a response is wholly lacking, it would furnish an admirable subject for a thesis investigation in some of the college laboratories.

THE MOVEMENT FOR PURER WATER SUPPLIES.

The short article, by an English engineer, on the protection of water supplies, printed in this issue, relates to a question which is attracting public attention to a very great degree, and is certainly destined to lead to very important action by a large proportion of American cities. Engineers and sanitarians have for many years clearly understood the intimate relation between polluted water and certain types of disease; but the general public is only now arriving at a clear comprehension of this relation. Ten or twenty years ago cities and towns were not at all particular about the quality of public water supplies, provided pollution was not apparent to the senses. Now, however, there is a genuine public demand not only for clear water, but for pure water. The public, after years of skepticism, has at last accepted the fact that typhoid fever is a constant source of danger to every user of a water supply polluted with sewage, and there will be no peace hereafter for those responsible for the water supply of any city in which a typhoid epidemic appears.

It is a very large and difficult problem which the engineering profession of America is to be called on to solve, in giving pure water to our cities, and Mr. Cartwright's brief summary of the "lines of defence" against water pollution adopted in England gives much food for thought.

As he states, English cities are now striving to gather their water supplies from uninhabited districts, and they have even in some cases purchased the entire drainage area from which their supplies are drawn in order to control it and prevent pollution. The water drawn from these areas is in many cases also filtered as an additional safeguard.

To the American engineer such measures must be at once set aside as quite out of the question, save perhaps for a few cities which draw supplies from mountainous regions. It is possible by legal enactment and proper sanitary policing to greatly reduce the pollution of streams used for water supply; but in this country not one city in five hundred can expect to buy and depopulate the entire catchment area from which its water supply is drawn.

Nowhere is the problem of good and safe water supply any more difficult, probably, than in the rapidly growing cities of the central west. There are no tracts of barren mountains or moorland from which they may draw their supply. The streams of the region drain a densely populated and highly cultivated agricultural district. Being fed by surface rainfall only and not by springs, they are subject to great variations in the rate of flow; and this means that a city must be supplied from a stream of considerable size, draining a large area of country. It is practically inevitable that any such stream will be more or less contaminated with sewage and hence it must be purified artificially before it will be safe for household use.

Filtration is doubtless the general method which will be used for the purification of a large proportion of the public water supplies of the country, and an enormous amount of work in the construction of filtration plants is destined to be done.

It ought to be recognized, however, that the conditions of no two cities are exactly alike, and only competent engineering studies can determine the best plan for a particular city to adopt. For example, we print in this issue a very interesting article by an engineer in the South, advocating the more general development of underground sources of water supply for places of moderate size.

It is probably true that this source of water supply has been too much neglected. The public and engineers alike have not attached sufficient importance to the purity and the freedom from sewage contamination of underground supplies. The prodigal wastefulness of water so common in American cities has led us to pay too much attention to quantity and too little to quality. Particularly are these underground sources of water important in parts of the West and South where surface streams very generally carry clay in suspension and are on that account more difficult of artificial purification than the clear waters of the North and East.

A safeguard against water-borne disease whose importance ought to be better appreciated, is long storage. In the reaction from the old ideas concerning the self-purification of rivers, we have gone, perhaps, too far to the other extreme and are attaching too little importance to time as a factor in reducing the liability to disease infection.

It is a noteworthy fact that most of the great typhoid epidemics have occurred in comparatively small places, taking a water supply from small streams. Here the germs of typhoid were carried directly into the town's water supply in a very short time. Had the water charged with the typhoid germs passed into a lake or storage reservoir and remained there a month before use, the chances are good that other forms of organic life would have destroyed the typhoid germs.

New York City's comparative freedom from typhoid is probably due quite as much to the size of the great storage reservoirs in the Croton watershed from which the supply is drawn, as to the millions that have been spent on its sanitary protection.

These are facts that ought to be better known and appreciated by engineers as well as by the general public. The common idea regarding storage reservoirs on a water supply system is that they merely serve to provide for periods of drought and low water. It ought to be understood that they have a most important influence in protecting the community from the germs of water-borne disease. We may even reach the point of constructing reservoirs in order that the water may be improved in quality by its storage. In many cases of a sediment-carrying water, such storage reservoirs would be merely carrying out on a larger scale the present system of settling basins.

Where filtration is in use it will be necessary to store water before filtration rather than after, on account of difficulties with the growths of algae in the filtered water; but this would usually be advisable in any event as the stored water at flood seasons will deposit its suspended matter before filtration and this will considerably lessen the labor of operating the filters.

There can be no doubt as to the public demand for pure water. Cities are not only desirous of a safe water supply, but are willing to pay its cost as they were not a dozen years ago. This means, if we mistake not, that a great many millions of dollars are to be spent during the next decade in the construction of filters, dams, reservoirs, and pumping machinery in connection with engineering works for purer water supplies. This means, too, as we have frequently pointed out before, that pure water is going to cost more than the present polluted water supplies, and that it must be distributed and used far more economically. By stopping needless waste and eliminating extravagant habits in use, pure water supplies can be furnished to many cities which would otherwise be financially unable to obtain them and would be compelled to go on using polluted water for an indefinite period.

LETTERS TO THE EDITOR.

Remarkably High Records for Compressive Strength of Stone.

Sir: In your issue of April 7 you refer to a test of trap rock recently made in this city which developed a strength of 42,500 lbs. per sq. in., and comment on it as something very unusual, and state that there are no recorded tests of granite or other stone which gave such strength. You ask for information from readers having data on similar tests, so I take this opportunity to give you the following record of some high test results which I have obtained.

Granite, Connecticut Valley—43,300 lbs. per sq. in.
Granite, Connecticut Valley—40,840 lbs. per sq. in.
Average of 23 tests from same quarries gave 35,000 lbs. per sq. in.
Bluestone, Hudson River—41,422 lbs. per sq. in.

Bluestone, Hudson River—38,000 lbs. per sq. in. Did not fail. Reached capacity of machine.

Sandstone, Potsdam, N. Y.—42,804 lbs. per sq. in. Did not fail. Reached capacity of machine.

Vitrified brick, New York—Two samples stood over 38,000 lbs. per sq. in. and did not fail. Reached capacity of machine.

All the above except one bluestone were on nominally 2-in. cubes, and were prepared by sawing and rubbing, but were not polished. A small specimen for test should never be hammer dressed.

The above are not the only high record tests I have on building stones, but they are enough to show that 40,000 lbs. per sq. in., while unusual, is not a phenomenal figure to obtain. My own opinion is that the figures given in most handbooks and textbooks for strength of stone based on laboratory tests are too low. The majority of the records given are taken either directly or indirectly from Gilmore's Report on Building Stones, and I am positive that many of his results are too low, for I have made a great many tests which contradict him.

In this connection I might mention that a few years ago I made a series of tests on the strength of the mineral jade for the late Heber R. Bishop, of this city, and we obtained a maximum strength of 95,000 lbs. per sq. in. on 1-in. cubes. Several cubes gave over 90,000 lbs. These tests I do consider phenomenal, and doubt if their equal has ever been found in a mineral material.

Ira H. Woolson.

Columbia University, New York City, April 19, 1904.

(In the appendix to Merrill's "Stones for Building and Decoration" is given a table of the strength of several hundred specimens of stone from all parts of the United States. The highest figures given are 29,270 lbs. per sq. in. for a slate from Brownville, Me., and a very small number of specimens of any stone had a crushing strength above 25,000 lbs. We shall be glad to hear from other laboratories which have obtained such high records as those recorded by Prof. Woolson.—Ed.)

A Satisfactory Overhaul Clause and Some Remarks on Specifications and Their Interpretation.

Sir: I have been reading with a great deal of interest the remarks in your journal on the subject of specifications, and the duties of the engineer in properly construing them. As we all know specifications are often copied from old ones, which probably answered all the purposes for which they were originally compiled, but are frequently worse than none at all for the work in hand, on account of difference in conditions.

Several years ago I had direct charge of the location and construction of quite a difficult piece of railroad in the Rocky Mountains, and as we had been having more or less difficulty on account of the question of classification, and were preparing to contract considerable new work, it was decided that we would have but two classifications of material, "earth" and "solid rock." We used the usual specification for "solid rock": "All rock in place and all boulders measuring one cubic yard or over," etc, and "all other material of every kind and nature to be designated as earth." It so happened that for a mile or more, where but little rock showed on the surface, there developed a mixture of clay and small stones in which there was just enough lime to cement the mass together, and while it was harder to move than the ordinary material, yet if it had been in an open country where it could have been got at, instead of upon a mountain side, it could have been plowed with four horses without difficulty, but instead of that the contractor did, in a few instances, use a little powder. The contractor made no claim at the time that he was handling anything else but earth, but when the work was all done and final estimates made, he concluded that he wanted pay for "solid rock," and, to make a long story short, brought suit in United States Court. The contractor when being cross-questioned as to whether the material was "solid rock" under the specifications, said "that it was as hard as solid rock." The judge then broke in, saying: "Anything that is as hard as solid rock is solid rock." From that time on we knew about "where we were at." The instructions to the jury were given regardless of all the other evidence and regardless of the express terms of the specifications.

As to specifications for "overhaul," it seems to be the one question which few engineers understand alike, and while most specifications are intended to arrive at the same object, yet they are, as a rule, understood differently. I have never seen but one set of specifications which seemed to me to cover the question thoroughly, and they have been in use by a very prominent Western railroad company for years. They relieve the contractor of putting any price in his bid for "overhaul," by simply stating that the contractor will be paid 1 ct. per cu. yd. per 100 ft., and that "overhaul" commences as soon as any kind of appliance is necessary to move the material beyond shoveling distance. In other words, 10 cu. yds. moved 10 ft. is equal to 1 cu. yd. moved 100 ft. With this specification the contractor knows exactly upon what to base his prices in making his bid, and I never heard of any trouble on the subject for want of understanding.

It is fair to say that, as a rule, there is not sufficient time and thought given to the drawing of specifications. It seems to me that it is as easy to draw up a set of specifications for ordinary work, so there can be no two ways of interpreting them, as it is to draw up any other simple document. Remember that the first man who has to arrive at the meaning and intent is the contractor, and while he may know from long experience at just what price he can move material under any and all circumstances, yet he may not have the requisite knowledge to enable him to reconcile ambiguities, and instead of asking for any enlightenment he simply "adds 10% to cover misunderstandings," and lets it go at that.

Yours truly, P. F. Barr.

Phoenix, Ariz., March 28, 1904.

Water Purification and Typhoid Fever with Reference to the Water Supply at Zurich, Switzerland.

Sir: We have closely followed the discussions recently published in Engineering News regarding water purification and its influence on typhoid fever. To illustrate the effect of purification of contaminated water by a sand filter, we would like to call the attention to the results obtained at Zürich, Switzerland.

The city of Zürich with a population of 153,000 inhabitants, is situated at the lower end of "Züricher see," around the outlet river, Limmat. The lake "Züricher see" is about 23 miles long, and averages about 2½ miles in width. The adjoining land is very well cultivated and fertilized by all kinds of natural fertilizers. About 20 villages with populations ranging from 1,000 to 8,000 are situated around the shore, and dispose of their sewage by emptying it into the lake. Part of this sewage will, of course, settle in the lake, but the remaining part has to pass the inlet of the water supply of Zürich, before it flows into the river Limmat. Frequent cases of typhoid fever resulted from using this contaminated water.

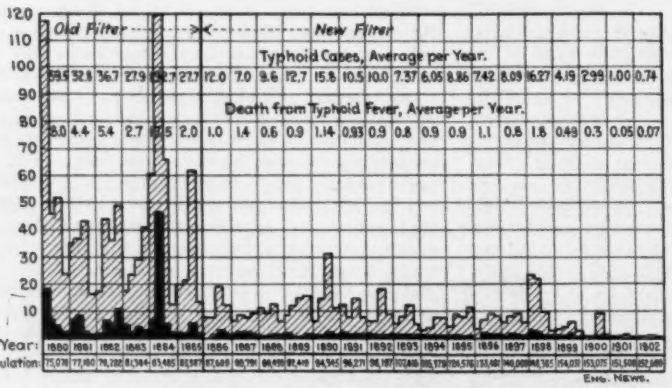


FIG. 1. DIAGRAM SHOWING RATE OF PREVALENCE AND MORTALITY FROM TYPHOID PER 10,000 INHABITANTS IN ZURICH, SWITZERLAND, 1880 TO 1902.

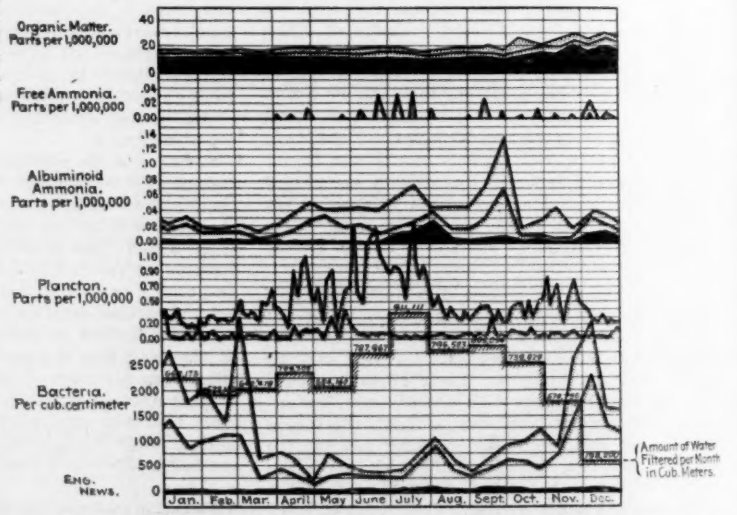

Organic Matter. Parts per 1,000,000
Free Ammonia. Parts per 1,000,000
Albuminoid Ammonia. Parts per 1,000,000
Plancton. Parts per 1,000,000
Bacteria. Per cub. centimeter
Amount of Water Filtered per Month in Cub. Meters.
Jan. Feb. Mar. April May June July Aug. Sept. Oct. Nov. Dec.
ENG. NEWS.

FIG. 2. DIAGRAM SHOWING CHEMICAL AND BACTERIOLOGICAL ANALYSIS OF ZURICH WATER, TAKEN RAW AND AFTER FIRST AND SECOND FILTRATIONS.

The following shows the average figures for typhoid cases and deaths per 10,000 inhabitants per year:

	Typhoid cases.	Death from typhoid fever.
Old filter, 1880-1885	62.88	6.67
New filter, 1886-1902	8.27	0.8

The water-works at Zürich consists of a filter plant, situated in the Industriequartier about 6,000 ft. from the lake, the main pumping plant at Letten, about 1,000 ft. from the filter plant, both on the bank of the Limmat, and a series of reservoirs, located at different places corresponding to the four zones in which the city system is divided. The pumping plant is combined with an electric power plant, both operated by water power from the Limmat. About 1,200 HP. is available. An extra steam plant of about 500 HP. is provided as a reserve.

The intake for the city water is located in the lake, about 1,000 ft. from the shore, and 13 ft. below the water level in the winter time and 50 ft. in the summer time.

The filter plant effects a double filtration of the water, which passes, first, through the preliminary filter (fore-filter) and afterwards through a fine filter.

The filter plant is divided into ten individual sections, arranged in two rows on both sides of the pipe system and the two small reservoirs for filtered water. Each of the filter sections has 7,250 sq. ft. effective fine-filter area, and 750 sq. ft. fore-filter area.

The fore-filters are built on piers in the fine filters under the same roof, and were erected after the plant had been in operation for some years, in order to increase the capacity, and make the purification of the water more effective and cheaper. The depth of the sand layer is about 4 ft. in both filters.

A special arrangement is provided for cleaning the fore-filter, as this takes out about 95% of the suspended matter in the water, and consequently requires frequent cleaning. This is done every day or two by means of water and air forced into the filter at the bottom, through a pipe system. The wash water, containing practically all the mud, flows out of the filter through the overflow. About 20 to 30 minutes is required for this cleaning, which is so thorough that even with badly polluted water the filter material can remain in place from six months to one year before it is taken out, washed by machinery, and reused.

During the cleaning of the fore-filter the continual work of the fine-filter is not interrupted, as the water level in the latter sinks about 5 ins. only during the cleaning of the other filter. The result of this arrangement is that the fine-filter remains in perfect working condition for two to four months before any renewal of the sand is required, as only a small amount of suspended matter finds its way through the fore-filter. The objectionable variation in the capacity of the filter plant is thus prevented; and the duty of the fine-filter is mainly to take out the bacteria. The rate at which the water flows through the fore-filter is from 7 ft. to 9½ ft. (about 60 U. S. gallons per sq. ft.) per hour. The filtered water is conducted into two small reservoirs, and flows by gravity to the pumping plant at Letten, from which it is delivered to the different reservoirs for the city supply.

The chemical and bacteriological conditions of the water are shown in Fig. 2. It will be noticed that the amount of organic matter taken out by the fore-filter and the fine-filter is about the same, that the free ammonia is practically disposed of in the fore-filter, and that albuminoid ammonia is very much reduced, especially by the fine-filter. About 95% of plancton, and in some instances over 50% of the bacteria, especially the parasitic, is retained in the fore-filter. The total amount of bacteria removed from the unfiltered water reaches 98½%, leaving only from 50 to 80 organisms per cu. cm. in the filtered water, while the unfiltered contains up to 3,500 bacteria per cu. cm.

K. & R. Tanner.

Gilfillan Block, St. Paul, Minn., April 1, 1904.

The Validity of the Hennebique Patents for Reinforced Concrete.

Sir: In your issue of April 14 you published a letter by Mr. L. J. Mensch in which this gentleman states that the Hennebique patents were declared void. This is a very partial statement, and is made in order to have your readers believe that reinforced concrete is a free construction and not patentable. The facts of the matter are that the Hennebique patents have been in court proceedings twice. The first time the proceedings were against Cottancin and the final decision on this was rendered by the Court of Appeals at Paris on May 14, 1902. It was declared that the Hennebique patents were valid, and a decision was rendered for the full claims made by Hennebique. The second action was brough against Boussiron & Picketty, and this action is not yet settled, and is pending before the Court of Appeals, which will render a decision in a few months. We shall be indebted to you if you will publish this in order to set this matter clear before the public.

Yours truly, Hennebique Construction Co.,
B. Baffry, President.

New York, April 22, 1904.

The Use of the Letters, C. E.

Sir: It seems to the writer that Mr. Barton, in his communication in your issue of April 7, attributes too great a value to the title "C. E." It has been my observation that men of large experience, whether graduates of technical schools or not, seldom write the letters after their names, but if they use the title at all are very apt to write it out in full, as Civil Engineer.

But the idea of confining the right to use the symbols to young graduates fresh from school seems rather funny, to say the least. If confined at all, why not restrict it to those who have had, say, a certain specified time in responsible charge of work, such as entitles one to membership in the American Society of Civil Engineers when properly endorsed. Those of us who have had experience with the young graduate who has been sent out to be "broken in," in the field, have usually found the young man far more anxious to use the title than is the "breaker."

Doubtless, if the title were protected it would be considered of more value than is the case at present, but let the protection be accorded those who really deserve it, which is not the case with the young student, no matter how bright, until he has added some years' experience to his theoretical knowledge. Yours very truly,

Frank S. Davis, "Civil Engineer."

1513 Wazee St., Denver, Colo., April 20, 1904.

Sir: Engineering News has lately printed a number of communications relating to the use of the letters, C. E., by members of the profession who have never had conferred upon them the degree of "Civil Engineer" by a technical school or institution. While the discussion of this matter is not new, some of the things said in recent communications, have set the writer to thinking again upon the subject, particularly as he has been one of the offenders, if it be an offense to use the letters C. E. after one's name, in the absence of a degree regularly conferred.

It is doubtless the fact that most members of the profession who place C. E. after their names, but who were not so fortunate as to have had the advantage of a technical course in a reputable school of engineering, have used the letters as a convenient abbreviation of the words "Civil Engineer" without any intention of violating the ethics of the profession or of creating a false impression in the minds of the public. The character of some of these men and their positions in the profession forbids the thought that they either desire, or have any need to sail under false colors. If convinced that they are doing wrong in the matter, they would undoubtedly be prompt to acknowledge their error, and to refrain from further offense. They will, however, wish to be convinced of wrong-doing before acknowledging their guilt.

The profession of Civil Engineering existed, and the words "Civil Engineer" were used to designate members of that profession long before technical schools for teaching the profession were established, or before such schools began to confer the degree of C. E. It will hardly be contended that prior to the time when the degree was established by such school, worthy members of the profession were not justified in calling themselves Civil Engineers, or in using the obvious abbreviation for the words. By what right then did the schools appropriate the name or its abbreviation and assume exclusive use of them? No one questions either the right or the expediency, on their part, of establishing and conferring a degree upon their graduates, or those of them who should merit the distinction. But why did they not adopt some distinctive designation not already in common use, as, for instance, a latin equivalent for the words "Civil Engineer," as was done in the professions of Medicine, Law and the Ministry? Worthy members of these professions may call themselves Doctors, or Lawyers, or Ministers, barring statutory prohibition where that exists, without being accused of pirating a title. What may a worthy member of our profession call himself if not a Civil Engineer? It can hardly be said that he may use the words in full, but not their abbreviation. As well might the quack doctor claim the right to use after his name the words "Medicinæ Doctor," while admitting that he is not justified in using the abbreviation "M. D."

If the schools adopted an indefinite name or symbol for the degree they desired to confer, whose fault is it? And if those unfortunates who have reached a recognized place in the profession, through paths that did not lead through the technical schools, choose to call themselves Civil Engineers, who shall say them nay? They have a prior right to the title.

The technical schools, and their worthy graduates, are entirely right in their general contention that unauthorized persons should not make use of the name or symbol that stands for an honor duly conferred, and represents a definite amount of hard study and worthy work accomplished. But if the words or symbols chosen to represent that honor are not sufficiently distinctive to avoid confusion with words or symbols already used to designate a general class, the fault would seem to be with those who adopted, originally, the ambiguous term or words to represent the degree.

It may possibly be not yet too late to remedy the defect. If, for instance, the letters E. C. were to be adopted and used by the schools to designate the degree of Civil Engineer, all danger of confusion would seem to be avoided. It would then be perfectly proper to brand as an impostor any one who should use the symbol without the proper authority. Impostor is a hard word, but from the position that the schools and their graduates seem now compelled to take, many of us who place after our names the words "Civil Engineer," or the only abbreviation standing for them, "C. E.," come under that category. The adoption of some other and distinctive name for the degree would relieve both parties to the controversy.

What has been said does not touch upon the general question: who is entitled to call himself a Civil Engineer? Unfortunately no accepted standard has been set up, either within or without the profession (excepting the degree conferred by the schools), by which the right to use the title may be judged. In the absence of such an accepted standard, every man is at least excusable for deciding for himself what he shall call himself. It logically follows that when we see the words "Civil Engineer," or their abbreviations, attached to a man's name, we may infer (though even that inference may not be justified by the facts) that his occupation is in some way connected with Civil Engineering. In themselves the words do not convey any idea of his ability or standing in the profession. This is, of course, all wrong. Every worthy Civil Engineer who has the honor of the profession at heart, to say nothing of his personal feelings of pride and self-respect, deplores it, and would welcome any practicable provision for separating the sheep from the goats. If he be the possessor of a degree won by a long course of hard study and subsequent worthy work, he feels very keenly the injustice of permitting ignorance and incompetence, plus "cheek," to sail under the same colors as himself. It is entirely natural and justifiable that he should protest when the C. E. is used by those who, from his point of view, have not had the degree conferred upon them in the regular way.

Even if it be assumed that the schools have acquired exclusive right to the use of the symbol C. E., it must be admitted that the degree represented does not always stand for a definite and uniform standard of ability and attainment. Most of the schools confer the degree upon those who not only have pursued and graduated in a thorough course of study, but have, in addition, had a certain amount of experience, and have shown capacity in their professional work. Others confer the degree upon those who have merely pursued creditably the prescribed course of study, regardless of any special ability shown; in which case it is rather a mark of industry than of superior merit. There are quite a number of men—and some of them have won their spurs in the profession—upon whom the degree of C. E. was conferred by a certain institution after a course of study covering but six weeks, the only textbook used being a well known engineer's pocketbook. Evidently, then, the possession of the degree does not necessarily disclose the standing of those who are entitled to use it, unless we know also by what institution it was conferred.

That it would be very desirable to have some uniform standard or test by which the right to call one's self a Civil Engineer might be judged, all will admit. The public, as well as the profession, would undoubtedly be benefited by prohibiting the use of the title except by those who have in some way (not necessarily by the aid of the technical schools) properly equipped themselves for practicing the profession. But in the present absence of such a standard or test, we are compelled to judge of each man's ability, not by what he calls himself, but by his fruits, his character and attainments.

When the question presents itself to us whether or not we are entitled to call ourselves Civil Engineers and make use of the abbreviation that stands for the words, each must now be governed by his own standard and his sense of propriety and modesty, bearing in mind that outside of the college degree the title means practically nothing.

It has seemed to the writer that when a man has practiced the profession honorably and faithfully, and with a fair degree of success for a considerable period of years, and has won an acknowledged reputation as a Civil Engineer, and particularly if he has been honored by admission as a "corporate member" to the American Society of Civil Engineers, or to some other civil engineering society whose standard of admission is equally high, he should not be considered presumptuous if he calls himself a Civil Engineer and uses the letters "C. E." after his name.

If such use is offensive to those who have had the degree C. E. conferred upon them let them see that the symbol of that degree be changed so that it will have a distinctive meaning, as suggested above. I am sure that most of us who are "outsiders," but who have a very high appreciation of the advantages of a technical education, would not only gladly recognize the graduate's badge of honor, but would join in the defence of his right to its exclusive use. S. Whinery.

95 Liberty St., New York City, April 18, 1904.

(The subject of the "C. E." degree and its significance—or lack of significance—was discussed at much length in the columns of Engineering News over a dozen years ago, and had much influence, we believe, in causing a number of engineering schools to abandon the practice of giving the C. E. degree to their students at graduation. At the present time most engineering schools give the graduates from engineering courses the degree B. S. (Bachelor of Science) and reserve the degree of C. E., or M. E., for bestowal as a post-graduate degree after the student has had some years of practical experience.

One other result of that discussion was the formal abandonment by this journal of the use of the letters C. E. or similar professional title after the name of an engineer. We adopted instead the practice of placing after the name of an engineer the letters indicating his membership in a national engineering society as "M. Am. Soc. C. E.," and this rule has been followed ever since. There are, we are well aware, objections to this practice also; but it seemed to us, then and now, to be on the whole preferable to the use of the title "C. E." or "M. E." in professional literature. Elsewhere the use of a society membership title is of doubtful wisdom, since the general public understands nothing of its significance, and is likely to misconstrue its use.—Ed.)

Hydraulic Diaphragms and Grain Pressure Tests.

Sir: The following contains some notes on the paper of Mr. J. A. Jamieson, entitled "Grain Pressures in Deep Bins," which appeared in Engineering News of March 10, 1904:

The hydraulic gages used by the author are supposed to be a direct measuring apparatus, similar to a pair of scales; but as the reaction induced by the raising of the mercury is a hydraulic pressure, i. e., a reaction equally distributed on the surface of the diaphragm, it can only measure directly, when horizontal, actions similar to itself, or pressures equally distributed.

When the gage, as in the case of model bins, forms the whole of the bottom, the measurements will be correct only if grain gives the same pressure per square inch over the whole bottom. We will see later on that this is not the case.

Let us now consider the gage vertical as shown in Fig. 1 of the author's (p. 237, March 10, 1904. Note that by mistake this cut was printed upsidedown.—Ed.). Before applying any outside pressure, the outer part of the diaphragm is subjected over the whole of the surface to the atmospheric pressure; but the bottom of the inner surface is subject to a reaction equal to the reaction of the top plus the weight of a column of water equal to the height of the diaphragm; the diaphragm cannot therefore be vertical but must bulge at the bottom as in Figs. 1 and 2 herewith, according to the height of the mercury column, the more so if made of thin rubber; and as the author shows (in his Fig. 4) that the acting resultants make with the horizontal an angle of 50°, it is difficult to see how the raising of the mercury can be a measure, exact or otherwise, of the pressure on an irregularly bulging surface, or rather of its horizontal component. The apparatus used by the author is not therefore so constructed as not to leave any serious doubts about its efficacy; and the fact that it may measure water pressures is no proof of its ability to measure grain pressures to any degree of approximation.

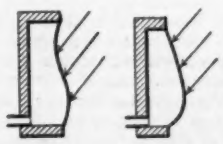


Fig. 1. Fig. 2.

In the tests made by the author the gage remained at

the same place and different heights of grain were poured into the bin. Although this mode of procedure appears to be logical, a priori, it is not absolutely so, as during the discussion at Montreal on Mr. Jamieson's paper, a well known elevator builder stated that the maximum pressure in a bin occurred at one-third of the height from the bottom.

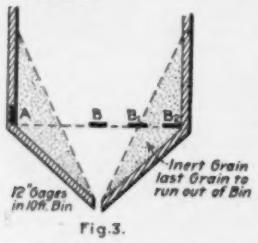


Fig.3.

During the same discussion, it was explained that tests in full size bins had been made at Quebec and Montreal with gages similar to the ones used by the author and located as shown in Fig. 3 herewith. The vertical gages were located at A, the same as in the experiments of the author, and the horizontal gages were located at B, B_1, B_2, on top of the grain, after the hopper bottom had first been filled up with grain. The pressures found (for grain evidently at rest) were as follows:

On gage B	5.5 lbs. per sq. in.
On gage B_1	4.66 lbs. per sq. in.
On gage B_2	2.91 lbs. per sq. in.

which shows that the pressure is not equally distributed on the bottom.

The tests made by the author, on grain at rest, are therefore opened to two objections:

(1) That the measuring apparatus did not correctly measure the pressure applied.

(2) That the pressures applied were not the maxima.

The tests made on grain in motion are more unsatisfactory yet, on account of the location of the gages. We must remark first that in the tests of model bins, the bottom pressure was always obtained with bin A (Fig. 2 of the author's), i. e., when side spouting. Even when side spouting, the pressures where transmitted to diaphragm B C through a thick mattress A B C of inert grain (see Fig. 4 herewith), which never was in motion, and there is nothing to show that the pressures would be the same when center spouting, or if the diaphragm was submitted to the direct action of the flowing grain. (It is difficult to see how, when center spouting, a diaphragm could be submitted to that action, as a cone of grain would form over the diaphragm, and the grain would flow around it; some other apparatus should therefore have to be devised to measure that action.) In the Quebec and Montreal experiments, arranged as shown in Fig. 3, diaphragms B fell with the grain when the valve was opened, and we have therefore no measurements of the vertical pressure of grain in motion.

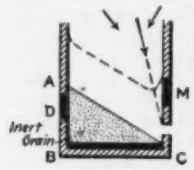


Fig.4

Coming now to the lateral pressures. In the center spouting tests, the gages were placed immediately above the hopper bottom, but the author shows in Fig. 2 B of his paper that the grain in front of the gage is inert, and says that the small triangular section did not move until the last; the location of gage A, Fig. 3, in the Quebec and Montreal tests was the same. In the side spouting test, diaphragm D, Fig. 4, was also protected by a prism of inert grain. Gage M, Fig. 4, is the only one which was submitted to the action of grain in motion, but was placed immediately above the valve. As soon as the valve is opened a portion of the grain in front of the diaphragm flows out and relieves the pressure, the whole mass slides down, applying the pressure again on the diaphragm, and the same thing happens over and over again, as shown by the curves in Fig. 8 of the author's; but there is nothing to show that a similar action would take place if the gage was located further up on the same wall in a full size bin, or at other points of the other walls. This peculiar action of the grain at that special point is also shown by the remark of the author that a 2-in. square gage placed at M did not register any pressure; the 3 × 12-in. gage at M did not therefore register pressure on the whole of its surface.

The tests submitted are not in any case tests of grain in motion; no tests have been made for the pressure produced by grain arching in a bin, preventing the flow of the grain (a not infrequent occurrence).

The peculiar action of gage M and gage D, Fig. 4, and the presence of an inert triangle of grain in Fig. 3 suggest analogies with the flow of a fluid. The increase of pressure on gage D, although protected by a mattress of inert grain, and the diminution of pressure on gage M shown by the curves in Fig. 8 of the author, would happen also if water instead of grain was flowing; and the diminution of pressure around contracted parts of the vein during the discharge of water, when the different threads of the vein cease to be parallel, is also fairly well illustrated by the inert triangle in Fig. 3.

The actions of grain at rest and of grain in motion seem to be very different and it is very singular that the pressures produced in both cases are exactly the same.

Coming now to the theoretical calculations, in which the movement of grain has not been taken into consideration.

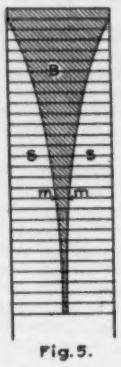


Fig.5.

The author takes in every case B as distributed over the whole bottom; but how this may be right is difficult to conceive. The author tells us that the full weight of the first layer rests on the second one and so on; that a part of each succeeding layer is carried by the walls and the rest by the next layer below. It must certainly be the part near the walls which is carried by them, and consequently the center part which rests on the bottom. The results of the step process are shown in Fig. 5, plotted according to the tables given by the author (Table III., p. 239). The portion SS is carried by the walls and the portion B represents the portion carried by the bottom. The vertical pressure at any height m is represented by the portion of B above mm and the pressure per sq. ft. is equal to $\frac{B}{mm}$.

The author takes in every case B as distributed over the whole layer; how this may be right is difficult to conceive. Taking for instance the bin 10 ft. square (Table III. of the author's): The grain put first in the bin is the bottom or eightieth layer and the full weight of that layer, or 5,000 lbs., rests on the bottom. It seems evident that any weight we put above cannot diminish the pressure of that layer on the bottom. But we find by the "Step process" that the pressure is diminished, in fact has nearly vanished; for when the bin is filled up there is only 1 lb. out of the initial 5,000 lbs. of the eightieth layer which is carried by the bottom, as shown by Col. 5.

But as there is no cohesion, the balance of the layer cannot transmit pressure from above, as it does not press itself on the bottom; and the pressure of the layers above can only be exerted through that part of the eightieth layer which presses itself on the bottom, i. e., on the 1-5000 part of the surface of the bottom.

The step process is not therefore a true representation of the action of grain. The process is really based on three assumptions: (1) That the vertical pressure, whatever may be the shape of the mass producing that pressure, is equally distributed on the bottom; (2) that the friction takes off a certain part of the weight of each layer; (3) that the lateral pressure per unit is equal to 0.6 of the vertical pressure per unit. It can be derived from them, in a simpler form, without any other theoretical or scientific considerations.

Calling B_{m-1} the weight resting on top of layer m,
L_m the total lateral pressure in layer m,
S_m the friction produced, and
d the diameter of the bin,
then assumptions Nos. 1 and 3 give, for a square bin,

$$\frac{B_{m-1}}{d^2} \times 0.6 = \frac{L_m}{4d}$$

$$\text{or} \qquad L_m = \frac{B_{m-1} \times 4d}{d^2} \times 0.6$$

$$\text{from which} \qquad S_m = \frac{B_{m-1} \times 4d}{d^2} \times 0.6 \times 0.41667$$

or as given by the author,

$$500 = \frac{B_{m-1} \times 4d}{d^2} \times 0.6 \times 0.41667.$$

In a 10-ft. bin this gives

$$S_m = \frac{B_{m-1}}{10} \qquad (1)$$

From assumption No. 2 we obtain:

$$B_m = B_{m-1} - S_m + X$$
$$= X + 0.9\, B_{m-1} \qquad (2)$$

where X is the weight of that part of layer $_{m-1}$ which bears on layer m.

Equation (1) gives

$$S_{m+1} = \frac{B_m}{10} = \frac{X}{10} + 0.09\, B_{m-1}$$
$$= \frac{X}{10} + 0.9\, S_m \qquad (3)$$

But $B_1 = 5000$ is the weight of the first layer, and equation (2) gives

$$B_1 = X + 0.9\, B_0 = X + 0 = X$$

Therefore $X = 5000$, and equations (2) and (3) are finally written:

$$B_m = 5000 + 0.9\, B_{m-1} = 10\, S_{m+1}$$
$$S_m = 500 + 0.9\, S_{m-1}$$

They constitute the "step process." Their values are given in Table III of the author's.

We have seen that the first assumption is disproved by the tests made in Quebec and Montreal, and that the first and second ones are disproved by the results of the "step process" itself. As for the assumption that for a given kind of grain there exists a constant relation between the lateral and vertical unit pressure at all points in the mass, it is contrary to all theories on pressure on retaining walls.

For, calling w the weight of a cubic foot of grain and L the lateral pressure, the author's formula:

$$L = \frac{5000 \times 40}{100} \times 0.6$$

can be written:

$$L = \frac{wd^2 h \times 4dh}{d^2} \times 0.6$$

or

$$L = w \times 0.6 \times h^2 \times 4d$$

Under that shape it is the old formula of the pressure against a wall of length 4 d, produced by a layer of depth "h" on another layer of the same depth, except that the factor 0.6 would be approximately 0.36, as long as the angle of repose meets the surface of the grain in the bins.

The factor 0.6 is therefore wrong at the beginning of the process, and it is easy to see that the limit does not depend on the factor itself but on the permanency of the factor whatever it may be. The permanency of the factor has been disputed by Rankine, Poncelet, Weyrauch, etc. That the factor varies, is also shown by Fig. 8 of the author's which gives the only results obtained with grain in motion, for side and bottom pressures in the same bin, and gives

0.33 for Diaphragm M (Fig. 4)
0.83 for Diaphragm D

at 75 ft. height, instead of 0.6 for grain at rest.

Some experiments by Mr. Prante on full-sized bins have been referred to in Engineering News (in an article by Mr. Max Toltz, M. Am. Soc. C. E.—Ed.), p. 232, Vol. XXXIX., in 1898, and also in the proceedings of the Institute C. E., Vol. CXXIX., p. 481, which shows pressures of 8 lbs per sq. in. for a bin 50 ft. high, instead of 2.45 lbs., as found by the author. It will be seen, by referring to the article (of Mr. Toltz.—Ed.) referred to, that Mr. Prante was not satisfied with his first apparatus and that he was perfectly satisfied with the reliability of the tests he made with his final apparatus, on grain in motion at or under the speed of 0.2 ft. per min.; but as tests made at a higher velocity were unreliable he could not deduce any law for the pressures as a function of the velocity. This is why the article says: "It is hoped that in further experiments surer observations and measurements will be permissible, with sufficient accuracy to determine the law of increase of lateral pressure with increase of velocity of movement of grain."

Mr. Prante's apparatus was described by the author during the discussion which followed the reading of his paper, and, being simply a pair of scales, seems to be a very good apparatus. It can certainly give exact measurements by first putting in the scale too big a weight and repeating the experiments with diminished weights until the correct one is arrived at. It is only a matter of a number of trials and does not necessitate any jerks nor any pushing back of the mass of grain.

Mr. Prante's experiments remain as the only ones made on grain in motion and measured directly by a measuring apparatus. The other tests, as we have seen, have been made with grain at rest, and in that case do not widely disagree with Mr. Prante's. When grain was in motion there are in the other experiments so many objections to the measuring apparatus itself and to its location, that the results obtained do not carry with them the certitude of their correctness.

H. E. Vautelet, Consulting Engineer.
78 St. Francois Xavier St., Montreal, P. Q.,
March 18, 1904.

(In accordance with our custom, a copy of this letter was sent to Mr. Jamieson, the author of the paper referred to, in order to give him opportunity to make a reply in the same issue. His reply is printed below.—Ed.)

Sir: Referring to the above letter, it will be noted that it is simply a criticism of the apparatus employed and the results obtained from the tests made by the writer, and is not based on any tests or experiments made by Mr. Vautelet. His assumptions, on which he bases his criticism, are not justified by the facts presented in the original paper, or from a clear comprehension of the subject which he has undertaken to discuss.

His Figs. 1 and 2, showing greatly distorted diaphragms, are purely assumptions. When the gage was being used to obtain the horizontal pressure and the face set parallel with the vertical wall of the bin, we used for the pressure-face a sheet of rubber packing 3-32-in. thick, which has very little stretch, but is still very pliable, and this was drawn and held tight, as shown by Fig. 1 (Eng. News, March 10, 1904, p. 237). When filled with water the bulging did not exceed 5-16-in., and even if it had considerably exceeded this, it must be self-evident that we would not measure the resultant of the vertical and horizontal pressures, since the vertical component must be all taken by the rubber diaphragm held at the top and acting as a swinging pendulum. We therefore get the true horizontal pressure, and this without any correction for our head of water, since the power exerted by the water in producing the deflection is simply stored in the rubber

diaphragm which, due to its resilience, will react as the pressure is applied to the other face. The pressure face of the 6-in. diaphragm has an area of 36 sq. ins. and the area of the mercury column was 0.00307 sq. in.; the receding of the face only amounts to 0.000174 in. for each pound of pressure per square inch, an amount so infinitesimal as to preclude any arching of the grain across the face.

When those diaphragms are placed in any location in a full-sized bin this pressure will be equal over the full face and we therefore get the accurate pressure at the point where the diaphragm is located. It has never been assumed or stated that the grain load was equally distributed over the bottom of a bin; in fact, before starting the tests in the full-sized bins it was anticipated that this would not be so, and therefore provision was made to place the diaphragms to obtain the vertical pressure, (1) directly in the center of the bin, (2) 1 ft. from the wall, and (3) intermediate, but the difference is not so great as to cause more than an infinitesimal difference over the face of a 6-in. square or round diaphragm, but if it should be so, then in every case the maximum pressure would be shown by the gage and any error would be on the safe side. In all cases it is the mean vertical pressure that is referred to in the calculations, which pressure was obtained for the full-sized bins by subdividing the horizontal area of the bin and multiplying by the respective pressures obtained.

It was also contemplated, in our original plans for testing, to place the diaphragm at every 10 ft. vertically against the bin wall, and one test was made 11 ft. 6 ins. from the bottom, which gave readings very slightly less for the full bin than the one placed 1 ft. 6 ins. from the bottom. This placing of the gage at different heights in the bin was, however, discontinued, since after consideration it was readily seen that the pressure must be the same 10 ft. from the top when the bin was full as at the bottom when the bin contained only 10 ft. of grain; and the records obtained proved this to be correct.

There was no statement made during the discussion of the writer's paper before the Canadian Society of Civil Engineers that the maximum pressure in a bin occurred at one-third of the height from the bottom. Mr. Max Toltz, M. Am. Soc. C. E., during his discussion, referred to the fact that in the bins of a very prominent steel elevator which had tie bars 5-16-in. × 5 ins. set on edge running across the bins, and the ends fastened to triangular plates which in turn were fastened to the Z-bar vertical stiffening members of the flat steel plate walls; that in operation a great many of the tie-bars had been pulled out by the vertical load due to the moving grain mass when the grain was being drawn out of the bin, and further explained that it had been found that the action of the moving grain mass turned the tie-bars over, with the face horizontal (which would not likely be the case if they were under high tension), and then pulled them away from their end fastenings, and that in nearly every instance this first occurred at about one-third the vertical depth from the bottom. This is very different from stating that the maximum horizontal pressure occurred at this point.

It is well known to experienced designers of elevators that tie-bars, or other obstructions running across a bin, when the grain is being drawn out are subjected to very heavy strains due to the moving column of grain, and this was clearly pointed out by the writer in his paper, as also the fact that there is a mass of grain near the bottom that does not run out until the last and that this is due to the influence of the bottom, which causes the area of the moving column to become more concentrated as it approaches the bottom, assuming the shape of a funnel, the exact angle of which we could not ascertain. It is believed that the combination of the above ascertained facts clearly indicates that the reason for the tie-bars failing at this point is as follows:

In a bin 13 ft. 6 ins. square and 85 ft. deep the horizontal pressure is practically as great 57 ft. from the top (but certainly not greater) as at the bottom, while the moving grain column most probably attains its maximum area at this point, and therefore the maximum strain on the tie bars, which is due to the vertical load to a much greater extent than the horizontal pressure.

Answering the criticism as to the tests in the model bins where the diaphragm forms the whole bottom, it was perfectly well understood when the tests were being made that the vertical pressure per square inch was greater in the center than near the sides, but in a bin of this size the difference is comparatively small, and is certainly not sufficient to distort the thin sheet-rubber diaphragm. One set of tests was therefore made with the grain resting directly on the rubber.

It must be evident that the rubber plays no part in the results since it simply acts as a separating film between the grain and the water, and since the area of the diaphragm was 144 sq. ins. and the water column used was 0.00614 sq. in. the receding of the diaphragm due to 1 lb. pressure per sq. in. is only 0.00118 in., and as the maximum pressure obtained in the model bin tests was less than ½ lb. per sq. in. it may be said that there was practically no receding of the diaphragm.

A series of tests was also carried out with the bottom diaphragm as above described, with the following additions (Fig. 6, herewith): We first placed a layer of flaxseed approximately ¾-in. thick evenly spread over the rubber, and on top of this placed a board which fitted neatly inside the top frame, and the grain in the bin rested directly on this board, which distributed the pressure and thus gave the mean pressure over the whole bottom.

To obtain the horizontal pressure a similar diaphragm, size 6 × 12 ins., was used, but without the flaxseed cushion, the board resting directly against the rubber and held against being pressed outward by the water by four small metal buttons attached to the frame and the points projecting slightly over the board (also shown in Fig. 6, herewith). Between the frame and the lower edges of the diaphragm board small wire rollers were placed to provide against friction due to the weight of the board and the vertical grain load; the board and the rubber diaphragm were thus perfectly free to move inwards, due to the horizontal pressure of the grain.

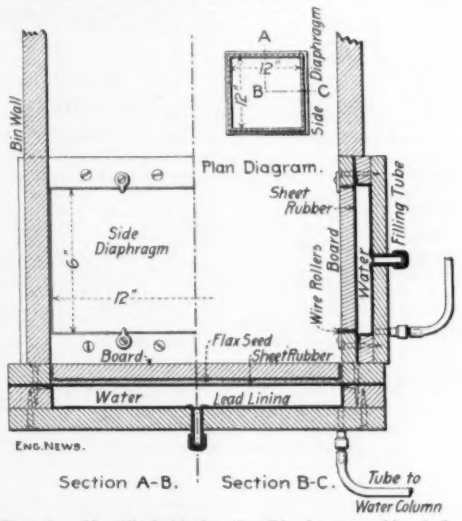


Fig. 6. Modified Hydraulic Diaphragms Used for Side and Bottom Pressure Tests on Model Bins.

Another arrangement taking the place of the two top buttons and the rollers between the board and the frame, consisted in suspending the board by means of two thin metal ribbons acting as pendulums, the top ends attached to the frame and the lower ends to the vertical center of the board, thus allowing the board to move freely inward, due to the horizontal pressure and the vertical load being taken by the pendulums. Both arrangements worked equally well and gave the same results.

In the two latter cases, however, it was necessary to add the pressure due to the initial head of water, to the obtained grain pressure, as since the diaphragm is rigidly held against being pressed outward it has no stored power or resilience to react. The horizontal grain pressure obtained by this latter arrangement plus the initial water pressure were almost identical for the same grain and bin as those obtained with the grain directly against the rubber.

There can be no reasonable doubt as to the accuracy of the pressures obtained and given in the writer's paper, every one taking part in the discussion before the Canadian Society of Civil Engineers, which extended over three full evenings, with the single exception of Mr. Vautelet, expressing themselves as highly satisfied with the apparatus as an accurate means of obtaining the pressures.

In reference to the location of the diaphragm to obtain the pressures when the grain was being drawn from the bin and therefore in motion, the statement that the true pressure would not be obtained because there is a body of grain in front of the diaphragm that is not actually in motion, is so clearly an assumption unwarranted by a knowledge of the nature of dry, strictly granular masses, as to leave considerable doubt as to its being seriously advanced.

The assumption that there is a large increase of horizontal pressure in an ordinary grain bin, due to the grain being drawn out, is unwarranted and fully disproved by our tests in both models and full-sized bins and by other tests made by Prof. H. T. Bovey, Dean of Applied Science, McGill University, and Mr. John Kennedy, Chief Engineer Montreal Harbor Commission, in full-sized bins of Montreal and Quebec elevators, and also by the many thousands of wooden grain bins throughout the country which, while amply safe for the pressures as actually ascertained, would not safely withstand any large increase of pressure, and there is no authentic case as far as the writer knows in over 20 years' experience, where a properly designed and constructed wooden bin has failed, due to the horizontal pressure produced by grain at rest or in motion.

Mr. Vautelet has put forward no practical or theoretical reason for assuming that the pressure is any greater when the grain is being drawn out than when the bin is being filled, and it is safe to say that no reasonable theory can be advanced for any large increase of pressure under ordinary working conditions, where the downward movement of the grain mass in the bin does not usually exceed 1 ft. per minute.

It is quite true that there is a slight increase of pressure when the grain is being drawn out, and that our tests have shown that it increases with increased rate of movement, but this increase has been found to be less than 10% under the maximum working speed when the gate is the centre of the bin bottom.

The writer has made very careful experiments with a view to ascertaining the interior movement of the grain mass when the grain is being drawn out of the bin, and it is believed has arrived at a reasonable theory for the slight increase of horizontal and decrease of vertical pressure when the grain is being drawn out of the bin, as actually found by the tests. This will be found in the discussion on the paper, which will be printed by the Can. Soc. C. E.

The meaning has not been made quite clear of the statement: "No tests have been made for the pressure produced by grain arching in a bin, preventing the flow of the grain," and which he states is "a not infrequent occurrence," but as the meaning was made more clear during Mr. Vautelet's discussion before the Can. Soc. C. E., I am enabled to reply.

It is possible, but extremely improbable, that in filling an elevator bin, a car load of dry grain should be put into the bottom of the bin, and the balance of the bin filled with grain containing a considerable excess of moisture, and then allowed to remain without attention until it heated to such an extent as to produce a large amount of cohesion within the mass. Then the car of good grain might be drawn out, leaving a vacancy, and the remaining material be temporarily held up by the walls and drop down in considerable volume. Under those, or similar conditions, the writer must plead ignorance to a knowledge of any means of testing for the pressure that might be produced; but we can say, that we have never known of an authentic case of this nature having occurred or damage done to a bin in this manner, and if it did occur, the grain would have become practically valueless, and it is more than probable that there would be a vacancy for a new elevator superintendent; and it would be equally ridiculous to design bins to meet such remote contingencies, as for your correspondent to design a through truss railway bridge of sufficient strength to withstand the shock due to the derailment of a train at high speed striking the truss.

Coming now to the theoretical calculations by the "step process," which were simply put forward to illustrate that the problem was capable of solution by the application of a little common sense and simple arithmetic, and it was believed capable of being understood by a schoolboy, if he chose to apply a little thought to the subject; it must have been evident that, while for simplification in making the calculation the bin is considered as filled, and calculated downward, the vertical pressure due to each layer is credited to the bin bottom, and the proportion of each layer properly credited to the walls, and exactly the same results are obtained as by starting at the bottom and filling and calculating layer by layer, until the bin is filled; but in the latter case the work of calculation is multiplied many times, since with each new layer added it would be necessary to follow the pressure through each layer to the bottom, or at least down to a point where the full weight of the top layer would be absorbed and carried by the walls. The calculation for the last layer alone would then be equal to the full calculation when starting at the top, and the results obtained identically the same.

It is noted that your correspondent has taken the writer's Fig. 12B. illustrating the proportion of grain weight carried by the walls and on the bin bottom (this was presented with the original paper before the Canadian Society of Civil Engineers, but not reproduced by Engineering News) and turned it upside down, making his Fig. 3, and is therefore attempting to disprove assumptions made by himself, and which are the reverse of those shown by the paper. Further comment on his Fig. 3 is therefore unnecessary.

There is no justification whatever for the statement that this process of calculating is based on three assumptions; it is really based on four factors, two of which (2 and 3) are definitely fixed by the dimensions of the bin, and the other two (1 and 4) were definitely obtained by the tests. The experiments to obtain the two latter factors were conducted entirely separate from the pressure tests; but factor 4, as thus obtained, agrees accurately with the results obtained by the bin tests made with the same wheat, and all the tests appear to prove the permanency of this factor, and we can conceive of no reason for anticipating a change in this factor for a strictly dry, comparatively hard, granular mass, unless the pressure should be sufficient to deform or cause one grain to be pressed into the other.

While conducting the tests we looked up existing information on retaining walls, and were therefore familiar with the theories on the angle of the resultant pressure

of earth against walls, which, however, is very different from a deep bin having four walls.

From tests which we have made it was ascertained that the coefficient of friction within the grain mass did not vary with pressures up to 6 lbs. per sq. in., and since the coefficient between the grain and the bin wall material did not vary with pressure up to 5 lbs. per sq. in., it would therefore appear to be well proven that this factor is at least constant within the range of ordinary grain pressures in bins of moderate dimensions.

Fig. 8 B (Engineering News, March 10, 1904, p. 242), curves m and n, have no bearing whatever on this factor, since the bin gate is located in the side of the bin, and when the gate is opened the centre of pressure in the bin is changed, and the arches or domes must take an entirely new form; but by reference to the curves it will be noted that when the gate is again closed the pressure on the side in which the gate is located (curve m) increases to nearly the normal for grain at rest, and the pressure on the far wall at the same time shows considerable decrease. The small plot circles in curves m and n, opposite to each other and nearest to the full bin curves for grain at rest, show the points where the gate was closed to weigh the grain and obtain the record, and the two intermediate readings were taken with the grain in motion.

As to formula by which to calculate the pressure of grain at all points in a deep bin, our efforts were not directed towards devising a formula by which to calculate the pressure at all points of a deep bin, since we found that there was a maximum vertical and horizontal pressure that would not be materially exceeded, no matter how deep the bin might be; and since that maximum is closely reached in all bins of practical dimensions, the simple formula, as given in the paper, for obtaining the maximum pressure is sufficient for ordinary practice. From the results obtained by the tests we have devised a table of "Pressure Factors," based on a unit of pressure both vertical and horizontal exerted by a column of standard grain 12 in. diam. or square; by this table the pressure in any part of a round or square bin of any dimensions and with varying coefficients of friction may be accurately calculated, and in a small fraction of the time necessary to obtain the pressures by any formula.

Referring to the tests made by Mr. Prante at Bernberg, Germany, the writer maintains that even if the structural details of his testing apparatus had been perfect, it would still be practically impossible to obtain reliable results with it; in fact, the obtained results would almost entirely depend upon the personal equation of the operator, and it is not surprising that Mr. Prante was under the impression that he found a large increase of pressure when the grain was being drawn out of the bin or that his plotted pressure curves for grain at rest do not agree with the obtained or calculated pressures of any other investigator. The reason for this can be clearly shown, but would require full drawings of his apparatus to be placed before your readers, to make the criticism clear.

It is only fair to Mr. Prante to state, for the benefit of those who have not had the opportunity of seeing his paper and drawings of his apparatus, that he recognized and points out a number of defects, among which was the tendency of the piston to turn or tip (and therefore jam in the opening), on account of the center not being on the same plane with its points of suspension and point of pressure, etc., and those defects were only partially remedied in his reconstructed apparatus. But the defects which he refers to are the constructive defects in his machines and are of less importance than the defects in principle referred to above. There is nothing in Mr. Prante's paper to justify your correspondent in making the assertion that "He (Mr. Prante) was perfectly satisfied with the reliability of the tests made with his reconstructed apparatus"; in fact, he concludes his paper as follows:

> For the present, I must leave the reader to consider the preceding tests, insufficient as they are, as a first contribution, which is to furnish an incentiye to further and more accurate tests.

The defects in Mr. Prante's apparatus are largely the inherent defects in any system of weighted levers for obtaining the pressure produced by granular masses, and illustrate the great superiority of the hydraulic diaphragm and mercury or water column gage, which makes a frictionless weighing scale that may be set in any position or angle; the receding of the diaphragm is so infinitesimal that there can be no arching of the mass over the pressure face to prevent getting the full pressure, and is in no way dependent on the personal equation of the operator, beyond a careful reading and recording of the pressures shown by the gage.

In conducting the series of tests to obtain the pressures and with a view to definitely ascertaining the laws governing the pressures exerted by granular masses, every effort was made to obtain accuracy. The tests in the model bins proved to be of equal value with those in the full-size or actual elevator bins, since it was definitely ascertained that the same laws apply accurately to all sizes of bins, while the latter permitted a greater variety of tests and more close observation. Both series of tests agree accurately with each other and also with the theoretical calculations based on the ascertained coefficients of friction within the grain mass, and between the grain mass and the confining walls, and it is believed that the laws governing the pressure of dry, strictly granular materials, stored in deep bins have now been conclusively ascertained—at least in all essential points.

The chief purpose in conducting the tests was to obtain accurate data for personal use in the design of fireproof grain bin construction and in presenting to the engineering public the obtained data every effort was made to give as full and clear a description of the apparatus employed and the manner of conducting the tests as consistent with time and space.

It is believed that the testing apparatus which was used is the best that can be devised for the purpose and that the obtained results are both accurate and reliable and require no defense. We, however, lay no claim to infallibility and will welcome criticism based on an intelligent study of the subject or on other obtained reliable data, which will assist in putting this long debated subject on a basis that may be considered final and conclusive.

J. A. Jamieson,
Grain Elevator Engineer.
Board of Trade Building, Montreal, Quebec,
April 15, 1904.

THE VICISSITUDES OF A PAVEMENT.

A correspondent sends us the verses printed below, taken from the Chicago "Inter-Ocean," which may be accurately described as containing more truth than poetry:

They took a little gravel,
And they took a little tar,
With various ingredients
Imported from afar.
They hammered it and rolled it,
And when they went away
They said they had a pavement
That would last for many a day.

But they came with picks and smote it
To lay a water main;
And then they called the workmen
To put it back again.
To run a railway cable
They took it up some more;
And then they put it back again
Just where it was before.

They took it up for conduits
To run the telephone,
And then they put it back again
As hard as any stone.
They took it up for wires
To feed the 'lectric light,
And then they put it back again,
Which was no more than right.

O, the pavement's full of furrows;
There are patches everywhere;
You'd like to ride upon it,
But it's seldom that you dare.
It's a very handsome pavement;
A credit to the town;
They're always diggin' of it up
Or puttin' of it down.

THE DAMMING OF THE RIVER THAMES, at London, is being considered by a Royal Commission. As there is a difference of 18 to 20 ft. between high and low tide, all larger vessels must be handled in docks that can be closed by tidal gates. The object of the Commission is to devise means for doing away with this inconvenience and thus increasing shipping facilities. Among the plans presented is one by T. W. Barber, M. Inst. C. E., who proposes a great dam across the Thames, extending from Gravesend to Tilbury. This would convert the river into a great inland lake, from Gravesend to Richmond. At the point selected for the dam the riverbed is firm chalk, and the structure would give a navigable depth of 65 ft. at Gravesend and 32 ft. at London Bridge, without any dredging. The proposed dam would be made of concrete, granite faced. The four locks would be 300, 500, 700 and 1,000 ft. long and from 80 to 100 ft. wide. The estimated cost is $18,200,000; but, as all docks could be left open, there would be an annual saving of $250,000 in the cost of operating the gates. The alternative plan of purchasing existing docks, says Mr. Barber, would cost $150,000,000, and $35,000,000 for improving and dredging the river.

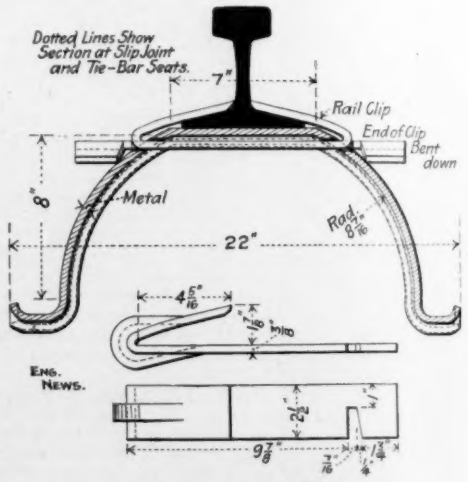
THE ALUMINOTHERMIC PRODUCTION OF PURE metals, free from carbon, is described by the inventor, Hans Goldschmidt, in the April number of "Electrochemical Industry." Powdered aluminum, when mixed with oxides of iron, copper, tin, lead, nickel, cobalt or other metals having a lower heat of formation, reduces the ores leaving an almost chemically pure metal. Of course the aluminum does not begin its reducing action until the mixture is raised to a certain critical temperature, but after that temperature is once attained the resulting chemical combination continues to give off sufficient heat to more than maintain the critical temperature and to produce the molten iron, nickel, or whatnot, upon which floats the slag of aluminum oxide. This process is being used successfully for welding iron and steel, and even for mending broken castings, but now it is proposed to produce metals free from carbon for use in making alloys. It is claimed, with much reason, that to produce alloys of perfect uniformity it is usually necessary to have metals free from carbon and other impurities. Reduction by aluminum can be so carried out as to produce metals not only free from carbon but practically free from aluminum by using a slight excess of oxide in the charge. Chromium, with a purity of 99%, is thus produced, and the reduction in a crucible, containing several hundred kilograms, is accomplished in less than half an hour.

The Goldschmidt Thermit Co., Wall st. Exchange Bldg., New York, are the American representatives of the inventor.

TRACK CONSTRUCTION WITH STEEL LONGITUDINALS.

The use of steel longitudinals as supports for railway track rails (in place of wooden or metal cross ties) has been advocated many times, and numerous designs of track of this type have been made and patented. While this form of construction was at one time used on several railways in Europe, little, if anything, has been done with such track in this country, but about two years ago a form of longitudinal support was designed and patented by Mr. Samuel E. Duff, Manager of the structural works of the Riter-Conley Mfg. Co. at Allegheny, Pa. Sections of this have been laid for experimental service on both steam railways and electric street railways. The design is based upon some ten years of experience in railway construction, and later experience with pressed steel work. It is intended to give a more permanent track with a better distribution of the load upon the roadbed, and to reduce the work now required in maintaining line and surface on track laid with rails on cross ties.

The longitudinals or girders are of the form shown in Figs. 1 and 2, being 7 ins. wide on top, 22 ins. wide over the bottom and about 9 ins. deep. They are made in lengths of 8 ft., and are connected by transverse tie-bars of channel sections 2 × 4 ins., these tie bars being 3 ft. 9 ins. apart, c. to c. Slots for the rail fastenings are formed in each side, and at one end the section is reduced for a length of 6 ins. to act as a slip



Improved Form of Clip.

Fig. 1. Steel Longitudinals for Railway Track Construction.

Samuel E. Duff, Allegheny, Pa., Inventor.

joint. The fastenings are bent steel clips, of the form shown in Fig. 2, the horizontal leg extending through the longitudinal and being bent down on the outside. The method of track laying is described as follows:

> The roadbed having been prepared as ordinarily, the ballast is placed over the area to be occupied by the girders to a depth of about 3 ins., or to the level of the bottom of the girder. The girders are then placed in position, the tie pieces acting as spacers to maintain the gage. While the girders are being laid the ends of each pair are lapped 6 ins. over the end of the preceding pair, and ballast is thrown within them from the ends. When enough girders and tie pieces have been laid the rails are placed on them, care being taken to have each rail

joint at about the center of a girder. The rail clips are then inserted in the openings in the girders and the ends are bent down to form a lock. The ballasting is completed by tamping in under the sides of the girders ballast sufficient to give them a firm and even bearing. While the tamping is being done the track can be brought to the required alinement and elevation. The ballast can then be placed between and outside the girders to complete the roadbed to the desired form.

The construction of street railway track is practically the same as that described above, but the girders can be laid in narrow trenches excavated for the ballast. As this track usually requires sharp curves, it is noted that the ordinary straight girders can be used for curves of over 500 ft. radius, special curved girders being used for sharper curves.

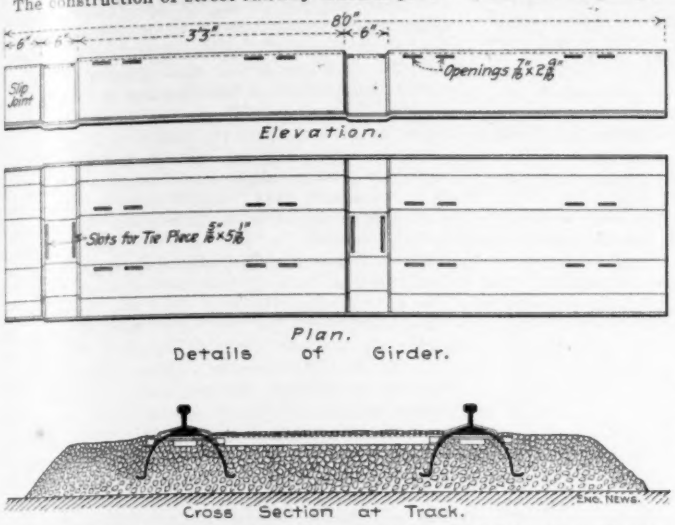


FIG. 2. DETAILS OF STEEL LONGITUDINALS FOR RAILWAY TRACK.

Material for 150 ft. of track was made by the Riter-Conley Mfg. Co., and the following additional particulars are from a letter from Mr. Duff:

The first criticism made by practical men who saw the material as it was manufactured, was that it would be impossible to so tamp the ballast under the girders as to support them uniformly under the inside of the arch, and that the girders would, therefore, open out at the bottom when the load was applied on the center of the top. In order to test this point I had four girders and the necessary tie pieces, clips and rails set up in the shop, and loaded them with steel plates weighing 102,000 lbs. The girders were supported on the bottom flanges only, resting at these points on strips of ¼-in. steel plate, which in turn were supported by wood strips 3 x 4 ins. Oil was placed on top of the steel plates so as to reduce to a minimum the resistance to horizontal movement on the part of the girder flanges. The maximum deflection observed was 5-16-in., the width of each girder out to out of bottom flanges being increased that amount. This opening took place when the first load of plates, weighing about 25,000 lbs., was placed, and little change was observed under the added weight. No vertical deflection of the top of the girder could be observed. From all appearances we could have added another 100,000 lbs. to the load without producing failure in the girders. This was a pretty good demonstration of the fact that the girder arch was sufficiently strong to carry the heaviest wheel loads without the possibility of permanently widening at the base.

The track was laid on the branch of the P., Ft. W. & C. Ry. leading to the Leetsdale Works of the Riter-Conley Mfg. Co., as shown in Fig. 3. At this point the track passes over a bank about 6 ft. high, composed of crushed slag, cinders, etc., which had been first made about four months before. In the course of a couple of months the whole bank had settled so much that it became necessary to repair and re-ballast the track. The operation of ballasting is clearly shown. This track remained in use about six months, carrying all the traffic passing in and out of the works. A sudden rise in the Ohio River caused a flood which cut about 1,000 ft. of the bank. A good deal of the track laid on wooden cross ties was carried entirely away by the current and drift, and one end of the 150 ft. of steel substructure was pulled out of line by this floating track. It was not pulled apart or damaged, but was thrown into line again with steel bars and jacks, and used for the regular traffic without relaying or ballasting.

At this time I arranged with the Pittsburg Railways Co. to make a test of this construction on the street car tracks they were relaying in Pittsburg. In August, 1903, it was laid for 135 ft. on Forbes St. I made a careful inspection of this track the other day, just after the snow had been cleared off of it by the first spring thaw. As far as it was possible to discover, the track was absolutely unchanged where laid on the steel substructure, but where laid on the wooden cross ties, the joints were open and some of them showed permanent deflection. The paving stones had sunk and cocked up around the cross-tie track, but were unchanged around that laid on the steel substructure.

The weight of the main-line track design of railway substructure is 110 lbs. per lin. ft. of track (supports for both rails), including tie pieces and clips. For the street railway design, the weight is 80 lbs. per lin. ft. of track complete. The weights per mile are 580,000 lbs. and 422,000 lbs., respectively. For the railway track, which is now laid in Forbes St., Pittsburg, the thickness of metal in the girders is ⅝-in. The tie pieces are ¼-in. thick. The clips are made from bars 2½ x ⅝ ins. In the street railway design, I propose to use 5-16-in. metal in the girders, the thickness of tie pieces and clips remaining about the same.

We have found that the clips constructed with a rib have no tendency to open out or otherwise release the rail, although we had some trouble with the clips as originally made according to the detail shown on the cross section in Fig. 1. Most of this trouble was caused by the clips not being made with sufficient accuracy to fit the base of the rail and the fillet where the base joins the web, but a rib can be pressed into the clip (as shown in the improved design) with very little trouble, and I have therefore adopted that detail as a standard. Should occasion require, or experience prove its necessity, the clips can be extended upwards so as to fit neatly under the head of the rail, and the rib pressed in the back of the clip made of sufficient dimensions to form a triangular brace for this top part of the clip. This would make the clip absolutely unchangeable at this point under any shocks or loads it might receive in ordinary use.

In regard to the other end of the clip, where it is turned down, we have found no wear or movement at this point so far as our experiments have gone. Using the 2½ x ⅝-in. clip, notched as shown, we have a metal cross section of 1¼ x ⅝ ins. left to take tensile strain. The part turned down against the outside of the girder is so thick in comparison with its length, that a great strain is required to deform it. Should experience prove that these dimensions we have used are insufficient the material can be increased as required without altering the design in any particular.

In regard to the adjustment for worn rails, we have found it possible to alter the gage of the track as much as ½-in. by the adjustment of the clips; the distance center to center of girders remaining constant. This is done by turning down the ends of the clip more or less, and by that means effecting a wedgelike action at this point, thereby moving the rail the required distance on top of the girder. You will note in this connection that no attempt is made to fasten the rail at the outside edge of base, but that the grip is intended to be at the point where the base joins the web. This admits of the use of rails of varying width of base, without any change in the girders or clips. The adjustment of the gage on account of the different width of rail heads may be easily made as just described.

As already noted, steel longitudinal supports for the rails, in place of wooden or metal cross ties, were extensively used at one time in Europe, more particularly in Germany and Austria, but at the present time this system of track construction is mainly confined to a few of the Austrian railways, the German railways which used it having mainly abandoned it in favor of the cross-tie system. The trouble was due in part to difficulty in keeping the ballast uniformly tamped under the rails, and in part to lack of strength and rigidity at the rail joints. There was also a serious wear of the top surface of the longitudinal, extending all along the bearing surfaces of the rail and being specially severe at the ends of the rails. This was due to insufficient strength of the track, leading to excessive deflection under trains, and the conditions were aggravated by the use of light rails, which had a wave motion independent of that of the longitudinals. This latter is an important point since it has sometimes been claimed that the use of longitudinal supports would enable lighter rails to be used than with cross ties.

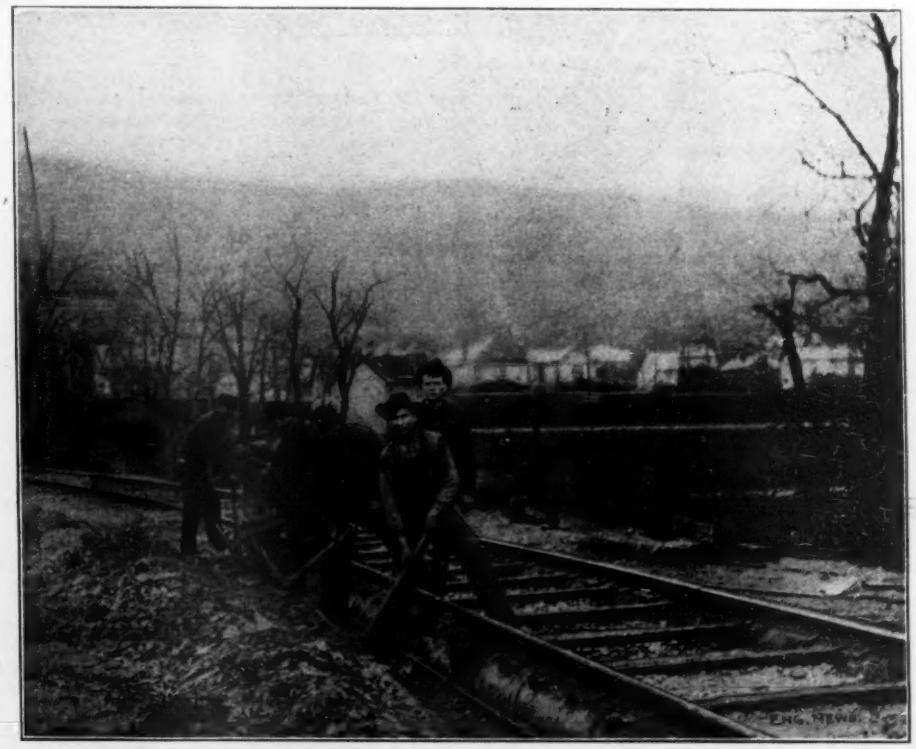


FIG. 3. BALLASTING TRACK LAID WITH STEEL LONGITUDINALS.

TYPHOID FEVER IN MINNEAPOLIS.

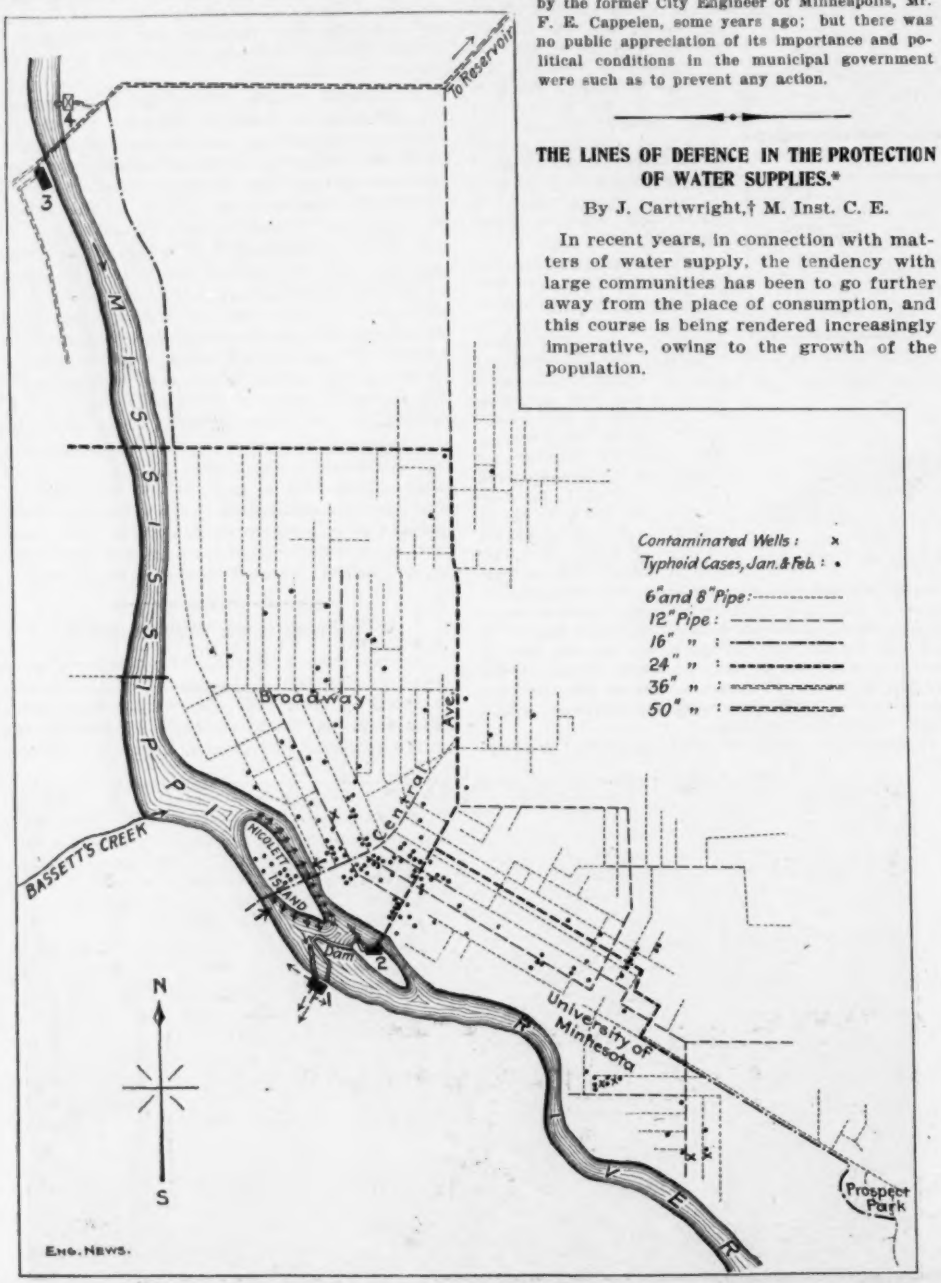
In our issue of March 3 we published an account of the typhoid epidemic in Minneapolis, prepared by Prof. F. H. Bass of the University of Minnesota. It will be remembered that the cause of the epidemic was directly traced to the water furnished by pumping stations located in the heart of the city where the Mississippi River is badly polluted.

The accompanying map, just received from Prof. Bass, shows in an interesting manner the distribution of typhoid cases along the mains supplied from the pumping stations Nos. 1 and 2 near St. Anthony's Falls. The epidemic during the first three months of the year followed close upon the starting up of Station No. 2 (which had been shut down for some time) on Dec. 30, 1903. It was

again shut down on Feb. 18, on account of the prevalence of typhoid, and the disease has since a rapid falling off. Prof. Bass reports the situation under date of April 12, as follows:

Sir: The typhoid epidemic in Minneapolis is decidedly on the wane.

In January	there	were	192	cases and	15 deaths.
In February	there	were	135	cases and	15 deaths.
In March	there	were	150	cases and	29 deaths.



MAP SHOWING LOCATION OF CASES OF TYPHOID FEVER IN MINNEAPOLIS IN JANUARY AND FEBRUARY, 1903, AND THEIR RELATIONS TO THE WATER DISTRIBUTION SYSTEM.

Most of the March cases occurred in the first part of the month and there have been not over ten cases since April 1.

The Engineers' Club of this city held a meeting, at which there was a large attendance, the attraction being the discussion of the typhoid epidemic and the water supply.

The ladies of the Improvement League of the city were carrying on a vigorous campaign for pure water for their children in the schools.

The School Board claimed it to be the duty of the Water Board (which is a committee of the City Council) and while the wrangle was on, a generous proprietor of the leading department store of the city offered to furnish free artesian water for all the schools. These ladies then were persuaded to continue the movement and urge pure water for the whole city. Many discouragements were met from various organizations and they were told that they never could "influence" the City Council to act.

The Improvement League held two public meetings, the first of which was attended by many of the leading citizens, some of whom spoke in very forcible terms. People began to get interested and soon the press of the city and all the before-mentioned organizations were forcing the matter in every way.

The result has been the permanent closing of Pumping Station No. 2, the proposed early closing of Station No. 1, and the appointment of a commission to prepare plans for the filtration of the river water pumped from Stations Nos. 3 and 4.

Filtration of the city water supply was recommended by the former City Engineer of Minneapolis, Mr. F. E. Cappelen, some years ago; but there was no public appreciation of its importance and political conditions in the municipal government were such as to prevent any action.

THE LINES OF DEFENCE IN THE PROTECTION OF WATER SUPPLIES.*

By J. Cartwright,† M. Inst. C. E.

In recent years, in connection with matters of water supply, the tendency with large communities has been to go further away from the place of consumption, and this course is being rendered increasingly imperative, owing to the growth of the population.

For those towns which can afford to go considerably beyond, to the uninhabited areas, this problem is not so acute, for at present there are nearly 4,000 sq. miles of wholly uninhabited land in large connected areas in England and Wales, of which 1,400 sq. miles are found in the mountains of Wales, a like area in the higher moorlands of the Penine chain, and 300 sq. miles in the Lake District. Over the whole of this area there is a very heavy rainfall, and the districts in question are well adapted for use as gathering grounds; the remainder of the ground is partly high land on the chalk and limestone ranges of southern and eastern England, partly fen and alluvial land, which is comparatively useless for gathering ground, chiefly on account of its low level—and a considerable portion of those eligible areas have already been secured for existing and projected waterworks. But for many authorities the only available sources of supply are not so favorably situated. The land from which the water is collected is largely arable, or, it may be, is sparsely inhabited, and to abandon the works which have been constructed and developed at considerable cost from time to time, as occasion arose, and go elsewhere, is altogether impracticable. Too often, in the past, sources of supply have been selected without any special regard to the character of the land over which the water flows, and quite frequently drainage areas have been fixed upon rather on account of their proximity to the district to be supplied, or to their available yield, than on the quality of the water obtainable.

Before expressing an opinion as to the best means of protecting our water supplies, it is, perhaps, necessary that I should point out the possible sources of pollution from which they require to be protected.

Without question the pollution which is most dangerous to man is that produced by himself. Hence the danger arising from the presence of human dwellings on the areas from which our water supplies are obtained, especially if they are situated in the immediate neighborhood of the streams or intakes. Many cases of serious outbreaks of typhoid, cholera and other diseases have been clearly traced to such sources of pollution; especially is this danger aggravated if the water is drawn direct into the mains from the stream or feeder at a point immediately below human dwellings, or from small reservoirs; for it is well known that large storage reservoirs not only facilitate sedimentation in the removal of suspended solids and mineral matter in solution, but also effect a very considerable bacterial improvement, especially if flood waters, containing large quantities of decaying vegetable matter, such as leaves and peat, are excluded.

At present the law does not give sufficient protection. Since 1847 there has been no general legislation for the protection of the gathering grounds of water-works, as distinguished from other watersheds, and while the Rivers Pollution Act, 1876, applies to all rivers and water courses, it does not contain any special enactments with reference to rivers and streams on which we are dependent for our water supplies; and it might with advantage be made more stringent and effective in preventing the fouling of water intended for domestic purposes, by enforcing penalties in cases of pollution and the supply of unwholesome water.

Some other methods of protection must, therefore, be adopted meantime, and it is interesting to notice the different steps taken by water authorities in this country, and also abroad, to attain this end. Germany depends upon filtration alone, and has spent millions in purifying turbid and polluted river waters; France and Austria have striven for mountain spring waters, and have built hundreds of miles of costly aqueducts to secure them; and in the United States, where the importance of protecting the gathering grounds is widely recognized, more favor is shown to making regulations and legal enactments for their protection than in owning them, and in several of the States very stringent measures have been adopted and are imposed. In this country, however, recent efforts have been directed to the purchase of the watersheds, thus securing their complete control and management entirely in the interests of the water consumer, which is certainly much more effective than protecting them by legal enactments.

Manchester was among the first authorities which acquired powers for purchasing the watersheds, although I claim for Bury the distinction of being the first to carry into effect the objects aimed at in thus securing complete control over them; and no doubt the experience gained by the Manchester Corporation in the Longendale Valley induced them to buy up the whole of the watershed draining to Thirlmere, extending to 11,000 acres. The corporation have since been amply justified in their action, more especially as the water is laid on direct from the lake to the consumers. Liverpool possesses the power to acquire the Rivington, as well as the whole of the Vyrnwy, watershed, the latter extending to 22,000 acres, notwithstanding that provision is being made for the

*Extracts from Presidential Address before the Manchester Association of Students of the Institution of Civil Engineers.

†Peel Chambers, Market Place, Bury, England.

whole of the water to be filtered. Birmingham has similar powers over the watersheds of its new supply from the rivers Elan and Claerwen, in Mid-Wales, reaching to 45,000 acres, of which 40,000 consist of open mountain pasture and moorland, carrying not more than one sheep per acre. Glasgow has adopted a different course, by entering into an arrangement with the landowners not to lease land for building purposes around Loch Katrine, nor within a drainage area extending to 20,000 acres; while Edinburgh, although it has a very complete system of filtration, and obtains its water from moorland very sparsely inhabited, protects its watersheds by contracts with the proprietors of the land and by legal enactments.

Other places might be enumerated which have adopted this precautionary measure, but there are many more which depend solely upon the efficiency of sand filtration. London may be cited as the chief example of this class, the Thames water, after extensive sand filtration, forming the principal supply; and in this case the area above the intakes is far from being uninhabited or uncultivated. Indeed, if one is to judge the merits of the two methods solely by a comparison of the prevalence of communicable diseases, like typhoid, or the death rate of those towns which represent both, his verdict must be in favor of the latter method. The typhoid case rate of London, for example, is remarkably low, being seventy-two, as compared with an average of 115 per 100,000 per annum for 219 towns in England, and there is no evidence to show that it has suffered to any appreciable extent from drinking the water drawn from a tainted area. The water supply of Hamburg is another instance of river water, after filtration on scientific principles, being chemically and bacteriologically as pure as it is practicable to obtain, and it must be conceded that those towns which drink river water, and depend upon the efficiency of filtration for its quality, are, generally speaking, the most immune from enteric fever. The conclusion from this evidence is, that bacterial purification in sand filtration, if carried out under skilled supervision, is effective in reducing pathogenic organisms, although it does not absolutely prevent their passage into the filtered water. Much depends upon the efficiency of the filter, which, unless properly constructed and worked, may be productive of more harm than good; several epidemics have been traced to the use of filtered water which had been polluted before filtration, showing that the filters had failed to remove the impurities, and that it is unsafe to rely upon them alone; and cases are not unknown where water has been grossly contaminated by being passed through filters. The health of towns and cities like London and Hamburg is largely dependent upon the thoroughness and efficiency with which the filtering of the water is carried out. If through carelessness of accident the water were allowed to pass unfiltered, or the filtering media of one filter-bed were allowed to become cultivation areas for pathogenic organisms, the result would soon be apparent in an epidemic—a condition of affairs which is not ideal.

It seems to me that, to prevent all possibility of pollution to our water supplies at their source, it is necessary for water boards or authorities—whose imperative duty it surely is to ensure this—to have full control over the watershed areas from which their supplies are obtained, and, where possible, to divert or stop up all public roads and footpaths. Where this is impracticable, to make provision for the drainage from public roads to be carried below the storage reservoirs or intakes, to clear all human dwellings off the catchment areas, and, as far as possible, prevent the incursion of tramps and others over them, and while utilizing them as pasture lands to prevent, by fencing, the access of cattle to the feeders or streams, and to take precautions against decaying vegetable matter being carried during floods into the storage reservoirs. This constitutes the first line of defence, and, if perfectly maintained, there will be absolutely no need for further precautions. But, unfortunately, it is difficult, and increasingly becoming so, if not altogether impossible, even while possessing full control over the catchment areas, to prevent a certain amount of trespass by people who, as in the case of the Maidstone epidemic, may be the means of polluting an otherwise wholesome source of supply. Recourse must, therefore, be also had to a second line of defence, that is, efficient filtration, not as we usually see it carried out in this country, but conducted on scientific principles, under competent supervision and systematic and frequent inspection.

To some this will doubtless appear altogether unnecessary, althongh in imperial affairs the wisdom displayed in providing a second line of defence, in view of the possibility of the temporary or complete failure of the first line, is seldom questioned, and surely the protection of the first necessity of life is as important as that of national prestige. At all events, it is the policy that is being carried out by the Bury and District Water Board, to which I am the responsible adviser, and also by important water authorities like Liverpool, Birmingham, Leeds, and others; and as the danger of relying exclusively on one or other of the systems is apprehended, the more enlightened policy of adopting and efficiently maintaining both will be proportionately and increasingly pursued.

UNDERGROUND WATERS ADJACENT TO SURFACE STREAMS.

By C. G. Hubbel.*

At certain favorable locations along the larger water-courses and at varying depths, there are considerable bodies of subsurface water, having a well-defined movement toward the river or stream and ultimately emptying into said stream. This water is contained in gravel beds, the size of the grains varying greatly, from that like rice to good sized cobble stones; the larger the gravel the greater the velocity.

The yield from these subsurface streams is dependent upon the length and width of the gravel bed, the water-shed tributary, and the size of the gravel itself, for if very fine, the head lost by friction keeps water from flowing freely, and although completely saturated it will not flow readily to a well, gallery or other collecting point.

This subsurface stream being almost invariably protected from surface contamination by an impervious bed of clay on top, the water is of great purity, as shown by bacteriological and quantitative examination, and this peculiarly adapts it for use as domestic supply for cities. The rainfall on the hills, where there is no impervious bed of clay, sinks into the earth and is taken up by the beds of fine sand (the "dug-well stratum"), and by the action of gravity, seeking a lower level, is finally collected into the coarse gravel and so on to its destination, viz.: the water-course, after having had the filtration obtained by flowing through several thousand feet of sand and gravel.

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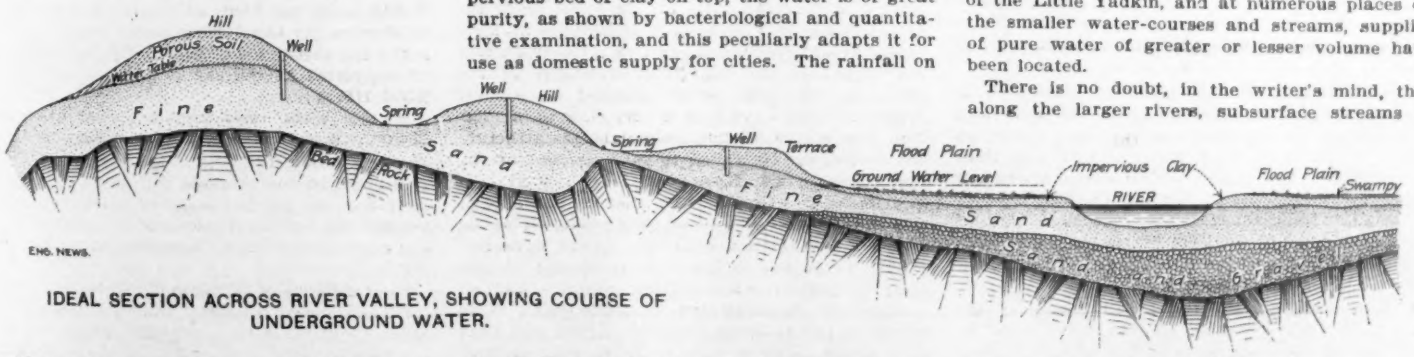


IDEAL SECTION ACROSS RIVER VALLEY, SHOWING COURSE OF UNDERGROUND WATER.

In the Southern States most of the surface streams are very turbid, nearly if not quite all the time, and before the water is suitable for domestic purposes, expensive filtration plants must be installed and maintained.

In the subsurface streams we have at once, pure water, filtered by nature's own processes, and the filters do not require maintenance or renewal.

The methods of obtaining this water are various, and of different cost, and no one plan will suit all conditions. In soils of some character and depth, the tube well system, consisting of a number of iron pipes of small diameter driven vertically into the gravel bed and connected to one main pipe, leading to a pump, will get the maximum supply; in other conditions, it is preferable to put in a central reservoir or dug well and force out pipes laterally, letting the water flow into the reservoir by gravity alone, from which it can be drawn at any time. If these lateral pipes be forced out for, say 100 ft. in different directions, they will draw from a large area. The most important part of this class of work is the survey, or location and accurate measurement of the underground stream and the estimate as to the amount of water obtainable, which should be done by first examining the water shed for favorable conditions as to porosity of soil, etc., and then making a line of borings across valley or basin to ascertain if suitable gravel bed is there.

If traces of gravel are found, the experienced "surveyor" can then trace it up to where it reaches maximum thickness, and by means of a number of borings clearly outline the "bed," and ascertain direction of flow by means of level of ground-water in each boring. The yield can be determined by actual pumping from test wells, with due allowance for time of year, as to whether wet or dry, and as to whether water rises in wells quickly when pumping is stopped.

The average depth of these subsurface streams is 25 ft. from the surface, although 50 ft. is not uncommon, and they frequently are as shallow as 15 ft., the depth apparently not affecting the yield or quality.

At South Boston, Va., in the flats of the Dan River, opposite the town, there was located a subsurface supply of this character, easily yielding 300,000 gallons per 24 hours. This quantity being amply sufficient, the investigation for a larger quantity was not made; but as the gravel bed was traced for about two miles in length and had an average width of 600 ft., there was undoubtedly a much greater amount available. This water was extremely pure and soft, and had a slope toward the river of about 7 ft. in a thousand, the gravel at bottom of bed being over 4 ins. in diameter, the bed averaging 5 ft. in thickness and 27 ft. in depth. The direction of the gravel bed was parallel with the river in this case, although the movement of the water was rather diagonal to the course of the river.

At High Shoals N. C., on the South Fork of the Catawba River; at Cooleemee, N. C., on the flats of the Little Yadkin, and at numerous places on the smaller water-courses and streams, supplies of pure water of greater or lesser volume have been located.

There is no doubt, in the writer's mind, that along the larger rivers, subsurface streams of many million gallons capacity per 24 hours can be located, thus obviating the necessity of providing filters for purification of surface waters, for water supply for larger cities and towns than those above quoted. In the large meadow lands adjacent to Salem Creek, near Salem, N. C., an available supply of subsurface water, of a maximum capacity of 2,000,000 gallons per day of 24 hours, was located; and in Eastern North Carolina, or the "sand hill" region, the quantity of

subsurface water obtainable is almost unlimited, and nature can attend to the filtration far better and more economically than man.

The city of Reidsville, N. C., is supplied with water from a subsurface stream running parallel to Richardson Creek, 300,000 gallons per 24 hours being obtainable, and provision being made for connection with the creek itself in case of fire.

MOMENTUM GRADES: SOME COMMENTS ON THEIR LITERATURE AND THEIR PROBABLE FUTURE USE.

By W. D. Taylor, M. Am. Soc. C. E.*

Though the energy stored in a moving body has been used long years by boys on sleds and on toboggan slides in surmounting ascents, by old-fashioned stage coaches in climbing hills on country highways, and by railroad trains in ascending grades, the principles governing the use of this stored energy seem never to have been scientifically set forth until quite recently.

In developing a practical theory on the use of momentum grades the engineering profession has followed in the wake of the practice of the trainmen, just as it followed in the development of the theory of the use of spiral curves, in the wake of the practice of the section foremen, who spiraled the ends of their curves as best they might long before the disciples of Holbrook, Searles, and Talbot came to their relief. The work of the sectionmen in spiraling curves has been greatly improved upon, however, by the engineer, once he was convinced that his efforts in favor of the parabola were of no avail and that the best railroad curve was a simple circular curve with spiral ends.

It could not have been otherwise than that as soon as the speed of moving trains began to exceed ten or twelve miles an hour, the locomotive runners began to notice the great advantage it gave their machines, both in the ability to surmount grades and in the ability to climb them quickly, to approach the foot of the grades at high speeds. To-day the use of the stored energy due to high speed is so common on the railways of America in surmounting grades and in making time on them that it would seriously interfere with train loads and time schedules on many railway divisions if a requirement for a uniform average speed between stations were rigidly enforced. For reasons not very difficult to divine the people in charge of the actual operation of trains on our railways have been loth to admit the extent to which they are dependent on the use of stored energy due to high speed in hauling heavy trains and in keeping their fast trains on schedule time. Many train operators will claim that a locomotive must not be sent out with a greater load than it can start at any point on the road, for a single train stalled on a busy road disarranges matters all over the division and even further. But if the Pennsylvania Railroad Co. can operate its trains over short stretches of 69-ft. grades when loaded for 47-ft. ruling grades, as stated by S. P. Hutchinson in the Maintenance of Way Association in 1900, less important roads can at least consider the matter.

As a matter of fact the use of high speed in all sags except those at stopping places is so well established on the railways that the trackman keeps up his track much better in such sags than at summits. "For," the section foreman will tell you, "every one of them hits this track at the foot of this hill just as hard as they can turn a wheel." If anyone doubts that the locomotive runner, at least on ordinary western or southern roads—even the runners of inferior trains, consider it to be their inalienable right to surmount hills by the use of the stored energy, let him cause to be issued to the average engine runner of a light local passenger train an order from the trainmaster to stop and put him off at the foot of a long grade where the train doesn't stop in its regular run; or let him get an order to have the local freight stop and unload a few bridge ties at the same place. When it was necessary in his younger days to get such orders issued the writer was always glad that train operating rules did not require that the order be delivered in person by the man responsible. At such times it was healthy to ride on the rear part of the rearmost car from the station where the order was issued to the stop.

The late A. M. Wellington was probably the first writer in this country who attempted to set forth in a scientific manner the principles governing the use of this stored energy. While Wellington's work on this subject is deserving of the highest praise, since he at least showed that the use of the stored energy could be explained by well-known mechanical laws, yet in his enthusiasm over the beautiful theory, he overstepped the bounds of prudence and made the good results accruing much better than could ever be realized in practice. Since 1887, when Wellington's book was published, many engineers throughout this country have made reports to railway managers in regard to the use of momentum grades, basing their conclusions on Wellington's incorrect deductions, and have either lead their superiors into trouble or been told with some severity that these fine-spun theories will not hold in practice. The result has been, to judge by available literature, to cast somewhat of a stigma on any attempt to place the use of momentum grades on a scientific basis. While the train operators continued to utilize the stored energy by rule-of-thumb methods, these practical men seem to have concluded that the definition of its use was beyond the learning of the engineer and made light of every attempt in this direction. As if to warrant the general ill opinion of all attempts in this direction, Professor W. G. Raymond, writing in the Railroad Gazette, April 17, 1896, said: "The writer has held . . . that the full theoretic effect of the energy stored in a train at a given velocity can never, or hardly ever, be utilized." Wellington made the great error of teaching that the stored energy might be spread out indefinitely over a long grade, while practical railway men have known for long years that usually under present limitations of train velocity the speed at which a heavy freight train will arrive at the top of any grade of greater length than two or three miles and of greater total height than 120 or 150 feet will depend more upon the efficiency of fireman and runner than upon the speed at which it started up the grade.

In Art. 404 of his Economic Theory, Wellington says (see Fig. 1): "Thus at A, moving at 50 miles per hour, the train is in the same condition mechanically as respects demands upon the motive power as if it were at A' 88.75 ft. higher moving at 0+ miles per hour." The meaning is that there would be no more demand upon the locomotive in climbing from A to B if the train reaches A at 50 miles an hour than if the road were level from A to B and the work required of the locomotive were simply to overcome the (level) train resistance from A to B at a slow velocity. As a matter of fact the ratio of the *horse power* required of the locomotive at A at 50 miles an hour on the actual grade, and exerting a tractive effort only equal to the total level resistance of the train, to the horse power required on a level grade at 0+ miles per hour is very close to infinity. And this is how Wellington's elaborate structure fell to pieces. He failed to take account of the limitations of the locomotive in this work, although he showed elsewhere that he had such a full understanding of those limitations. It seems singular that so many writers should have followed Wellington in his hazy treatment of this complex subject when current practice had so conclusively demonstrated its inadequacy. One writer in the Railroad Gazette in 1896 said that a 1% grade 25,000 ft. long of 250 ft. total vertical lift could be reduced to a virtual 0.94% grade by a velocity of 20 miles an hour at the foot of it. And this is true as deduced from Wellington. But that some of the practical men were alive to the use of the stored energy as well as to its limitations is evidenced by the fact that this very article was written in the discussion of a paper by Mr. Vaughan, of the Great Northern road, in which he had pointed out that for heavy freight trains it was of no avail to try to make use of the stored energy in surmounting grades of greater total height than about 120 ft.

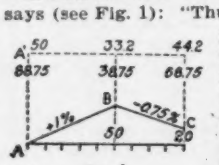


Fig. 1.

Professor C. Frank Allen, of the Massachusetts Institute of Technology, wrote a discussion of a paper in the Railroad Gazette of Jan. 12, 1900, by Mr. Chas. C. Wentworth, which paper will be referred to presently, in which he set forth the general subject of momentum grades after the manner of Wellington. That is, he treated the subject from a pure consideration of the physical laws of accelerated motion, assuming, involuntarily perhaps, that a railroad train is propelled by a machine (the engine), whose energy output can be varied at will and increased almost indefinitely with the speed. Professor Allen said in a second article, in reply to a criticism, that the article "was intended to develop somewhat more fully the principles underlying the question of momentum grades." Let us look into an example he offers as illustrating this use. The second example given is as follows:

Assume as conditions that the train passes station 0 at 25 miles per hour, and reduces speed to 10 miles per hour at station 60. The locomotive is to exert a uniform pull.

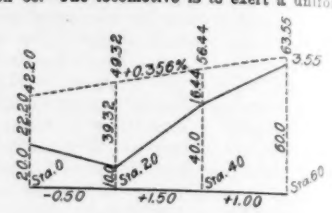


Fig. 2.

The virtual elevation at 0 = 20.00 + 22.20 = 42.20.
The virtual elevation at 60 = 60.00 + 3.55 = 63.55.
The virtual grade will be $\frac{63.55 - 42.20}{60} = +0.356$ per 100.
The velocity head at 20 = 42.20 + 7.12 − 10.00 = 39.32.
The velocity head at 40 = 42.20 + 14.24 − 40.00 = 16.44.
The speed at 20 = 33.3 miles and at 40 = 21.5 miles per hour.

Now, since the example was given to illustrate a principle we will suppose that it will fit all cases, including a train loaded for all the engine can pull up the uniform "virtual" grade of 0.356% at 10 miles an hour. Professor Allen might well claim that he has cut out such an interpretation of the example by the first two dozen words outlining the conditions, but the plain intent of the example seems to be to show that by using the velocities named the broken grade line can be operated as a virtual 0.356% grade. Suppose this train were pulled by the identical compound engine whose description and performance is fully given in Trans. Am. Soc. C. E., Vol. L., p. 5. This engine weighs about 130 tons (with tender), has 133,000 lbs. on drivers, and can exert a tractive effort at the contact of the driver treads with the rails of 26,300 lbs. at 10 miles per hour, making an output of about 700 effective horse power in so doing. The utmost effective output of this machine was less than 950 horse power. Now, since the engine "is to exert a uniform pull," it must make the same pull at station 10, where the speed is 33.3 miles per hour, as at station 60, where it is 10 miles per hour. This means that in order to make the theory hold, the 950-HP. machine must be converted in the sag into one of more than 2,300 HP.

If the train resistance increases materially with the speed, as nearly all experimenters have decided, and if the engine is "to exert only the pull required to overcome the level train resistance and the grade resistance along the virtual grade," the output required of the engine in the sag must be materially increased above the 2,300 HP.

The teachings of Wellington, Webb and Professor Allen are to the effect that if a train travels along the uniform grade A C D (Fig. 3) at a uniform rate, exerting a uniform pull just great enough to overcome the rolling and grade resistance along A C D, the drop C B can be introduced without detriment, provided only that the drop C B is not so great as to give too large a velocity head. "The train will gain in velocity from A to

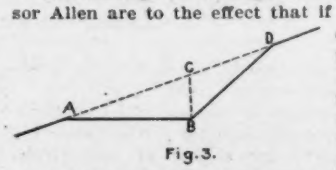


Fig. 3.

*Professor of Railway Engineering, University of Wisconsin, Madison, Wis.

B and lose velocity from B to D, reaching D with the same speed it had at A."

Now, as a matter of fact, if C B is so much as 20 ft. or more, the grade A D must be of a rate considerably less than that which limits the weight of the train in order that this broken grade may be operated as outlined. For, in order to carry out the scheme, the energy output of the engine must increase (uniformly) from A to B with the speed and decrease (uniformly) from B to D with the speed. For this reason such sags as that above are wholly impossible on ruling grades or on grades whose rate approximates that of the ruling grade except near the foot of them when the speed at A can be made quite different from that with which the train arrives at D.

In the summer of 1902 the writer received a letter from a distinguished member of the American Society of Civil Engineers, in which he said in effect that up to that date a correct exposition of the principles governing the use of momentum grades had not been published. There is no text-book written, so far as the writer is advised, from which all the information concerning, and the correct principles governing, the use of momentum grades can be learned. Webb's "Railroad Construction" was revised last year and a lot of matter relating to railroad economics was published in this second revised edition. On the second page of the chapter on the subject of "Grade" there is an article headed "Application to the Movement of Trains of the Laws of Accelerated Motion." This is followed by an article on the "Construction of a Virtual Profile," and throughout the discussion there is not a line to point out to the student the variable demands made upon the engine by the easily-spoken words, "assume that the engine continued to exert the same drawbar pull," nor a line from which he can infer that the operation of such grades as a "virtual" level is only possible with either very light trains behind powerful engines, or with very light and short grades, or both. So the student can read the whole discussion as given and grasp every point that is set forth without being able to acquire any adequate idea of the extent to which the stored energy may or may not be utilized in ascending grades. In the example given the engine is quietly assumed to vary its horse power 330%, which it is to do automatically, so to speak, under the conditions that "the throttle is not to be changed." It might at least have been suggested that for some trains on most roads the engine might refuse to accommodate itself to such varied demands.

The writer believes that it is unfortunate that this subject has been treated in this manner by engineering writers, for the reason that when such theories fail in practice, as fail they must and do, the confidence of every-day practical men who have to deal at close range with these matters is shaken in the result of all scientific investigation.

Having evolved one theory on "velocity grades" that would not work, and rested there for long years, it was high time that the engineer should evolve something in this line practicable and of lasting benefit if it could be done. That engineers are striving to accomplish something practicable in this line is evidenced by the following facts: Within a very few weeks the writer has received a letter from the Chief Engineer of an important Western road implying that he was trying to work out the question for the conditions on his road, and asking for sources of information on the subject; within the last nine months the writer has been in the offices of two other chief engineers of Western roads, representing more than 12,000 miles of road, and has been shown by them diagrams and calculations which they were evolving on this subject.

Now, before reviewing some of the really creditable work that has been done in this direction in recent years, the writer would propound the query, Is it not true that the only warrant that Professor Raymond could have for saying that the full theoretic effect of the stored energy could never be utilized in practice is because writers on this subject in working out their theories have imposed conditions on the locomotive which from its construction and limitations it could not meet?

Probably the first engineer who made any real advance over Wellington in the scientific treatment of momentum grades was Mr. E. H. McHenry, formerly chief engineer of the Northern Pacific, and now chief engineer of the Canadian Pacific Railway. The brief treatment of the subject of virtual grades in his remarkable booklet, "Engineering Rules and Instructions," shows that Mr. McHenry had a full conception of all the elements of the problem, and had he taken the time and had he considered the subject of sufficient importance, there is no doubt that he could have written all that was necessary at the time he issued his booklet to fully inform students. But since his system of "velocity grades" and "virtual grades" is built up on the basis of "mean traction" and "mean resistance"—the mean traction and resistance being the average values of those variables at the inferior and superior speed limits—the diagrams he evolves leave much to be desired in the way of flexibility, even if it is granted that they are accurate enough to express average results between the extreme limits.

In the use of momentum grades we not only wish to know how far up a 34-ft. (0.65%) grade a train which starts at 30 miles an hour and is loaded for a 21-ft. (0.4%) grade will run before its speed is reduced to 10 miles an hour, but we wish to know if the same train reaches the foot of that grade at 35 miles an hour what speed it will have after running a quarter of a mile up the grade or how far it can run up the grade before its speed is reduced to 15 or to 20 miles an hour. For on busy roads the schedule may be as important as the train load.

So what is needed is, say, a diagram for the heaviest trains of loaded cars and a diagram for the heaviest trains of empty cars—loaded for all the engine can pull up the ruling grade at the minimum allowable uniform velocity for that class of train, and the engine should be of the most unfavorable class used on the division for exerting traction at high speeds; from which diagram the performance of the train on all other grades likely to be used, whether accelerating or retarding, can be read off by inspection.

In an article published Dec. 8, 1899, in the "Railroad Gazette," Mr. Chas. C. Wentworth made some very interesting suggestions on the "Theory of Velocity Grades," in which article he offered some formulas which the writer believes more nearly embody the correct principles governing the subject than anything written previous to that time except Mr. McHenry's treatment of the subject. However, as pointed out by Professor Raymond, these formulas were unsatisfactory. They made the virtual grade, as Mr. McHenry assumed it to be, a straight line, though Mr. McHenry knew it to be, from his own definition, a curved line. He defined it to be "a gradient of equivalent resistance (at every point) to the force exerted by the engine."

The next paper in chronological order that gives desirable information on the subject to which the writer would call attention is the pamphlet issued as Bulletin No. 1 by the American Railway Engineering and Maintenance of Way Association, entitled, "Locomotive Tonnage Rating—Southern Pacific Ry." But the most authentic and comprehensive treatment of the subject yet written, so far as the writer is advised, is a paper and its discussion in the Transactions of the American Society of Civil Engineers, Vol. L., p. 1, on "Virtual Grades for Freight Trains," by A. C. Dennis. For the class of readers for whom it was intended the writer cannot suggest any improvement, as it seems practically to have exhausted the subject as far as may be, considering our present store of information. The writer is not ready to accept Mr. Dennis's conclusions in regard to the train resistance remaining so nearly constant through so great a range of speed as he found until the fact is demonstrated by a larger range of experiments, but that is a mere detail in the treatment of the subject. That which is of the utmost moment is that every factor that affects the velocity of a train on a grade is given due weight in deducing the velocity curves (for they are not virtual grades) shown in the diagrams. Given the engine traction at all speeds used in practice and knowing the train resistance at those speeds, though this information be difficult to obtain, the method used by Mr. Dennis of determining the distances run for each change of one mile per hour in the speed on various grades with a given train load and tracing his velocity curves through the points so determined cannot do otherwise than give a curve which approximates closely enough for most practical purposes to what the train will actually do on the road. The diagrams of Mr. Dennis, together with those of Mr. John A. Fulton and of Mr. Purdon in the discussion make up together the best graphical presentation of the subject the writer has seen. However, since the subject has not been fully treated elsewhere, it is a matter of regret that for the benefit of students Mr. Dennis did not treat the subject more exhaustively, ab origine.

Even when read in connection with his article in Engineering News, Nov. 22, 1900, on this same subject, the full import of Mr. Dennis's article is not readily grasped by students not familiar with the operation of trains.*

An attempt to define the value and use of momentum grade diagrams is an effort to enter a somewhat dangerous field. But it is true without doubt that the subject has not been utilized hitherto to anything like the extent that its real utility would warrant. It seems doubtful if momentum grade diagrams prepared by engineers on an operated road can be of any real benefit to the transportation department in regular train operation, assuming what has not always been true that the men in charge of that department are always eager to haul the heaviest loads at the fastest speeds consistent with economy. For, the positive information acquired by actual experience as to what each class of engine can do on each grade with each class of train is certain to be of more value than, and to supplant, a diagram worked out from theoretical conditions.

For these reasons the sphere of usefulness, in the future, of momentum diagrams is likely to be confined to lessening the first cost of construction on new roads and in figuring out economic savings in contemplated changes and grade reductions on operated roads. The former of these uses is likely to be restricted, for the reason that it is somewhat risky to introduce a grade dependent upon momentum on a new road for fear that the future development of traffic or of operation may require a stop where the train would have to acquire speed to surmount the grade ahead. This argument against momentum grades has been urged with more force than its merit warrants. It can not be urged too forcefully, however, in building a new road through a well-settled or mineral country. In the layout of such a line the engineer should never consider the introduction of momentum grades. But in the lay-out of such lines as the Kansas City, Mexico & Orient, and of the projected Canadian Grand Trunk, which lines will necessarily cross long stretches of barren country, there is no doubt but that momentum grades could be judiciously used to good purpose at many points; and there are many points on roads recently constructed in sparsely-settled districts where the introduction of momentum grades would have saved many a dollar in first cost of construction without imposing any handicaps on the transportation department. But in any country where a momentum grade is used the location

*That students manage to get through even our leading technical schools and graduate without grasping some fundamental principles was demonstrated in the following rather striking manner: On a certain engineering work the writer had two civil engineer graduates as his assistants. One was a graduate of a leading engineering school in the East, and the other of a leading Western university. Both had had some experience when they entered the writer's employ. One of these men was delighted beyond expression one day when in a conversation it dawned upon him that the effect of a grade in increasing traction could be exactly determined. The other was sent in charge of a small party to run in a 3-degree curve between two long tangents. After two days he returned saying that he had not succeeded and that he could demonstrate from actual measurements taken on the ground that those two particular tangents could not be connected by a 3-degree curve. He had made an error of 50 ft. in chaining in one of his sub-tangents, and taking them unequal, his demonstration from measurements "on the ground" could not be gainsaid. This experience suggests the query as to what is the stage of mind growth of a technical graduate who has not caught the practical import of the law of the inclined plane or who can conceive that any two straight lines cannot be joined by a curve of given radius. It does not follow that the minds of such men are not in a thriving condition, for both of these men did creditable work in other lines before and after this exhibition of weakness.

of the road ought always to be made with special reference to the reduction eventually to the ordinary grade, and the surveys for both lines should be made and mapped; and the estimates of construction of both lines should be made and filed, before the momentum grade line is constructed. Even this use of momentum grades, however, will be more and more restricted as time goes on, because there will be fewer and fewer lines built through sparsely-settled or barren districts.

But the great field of usefulness of momentum grade diagrams should be found in the reconstructions to lower grades and better alinement that are sure to come, on account of increasing density of traffic, to thousands of miles of railway in operation in the United States. In such reconstructions the traffic is known and the stopping places are fixed. In the reduction of practically every long grade on the road, the foot of which can be approached at high speed, there can be found a point on the grade below which it will not be necessary to change the road in order to adopt train loads and time schedules suited to the reduced grade. The part that can be omitted is often the most expensive part of the work. Most railroad managers insist on "doing the whole thing" when they begin an improvement of this kind, but that doesn't prove necessarily that it is always the best policy. Since the funds that may be used for such purposes are always limited, the grade reduction may be carried further if the work is done only where it is absolutely necessary, or, the rate or ruling grade to which the road is to be brought may possibly be lessened a few feet per mile.

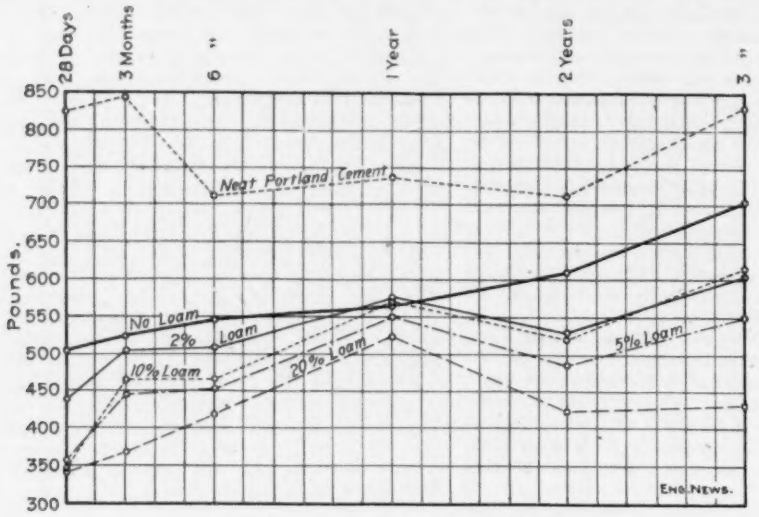


Fig. 1. Tests of 1 to 2 Mortar.

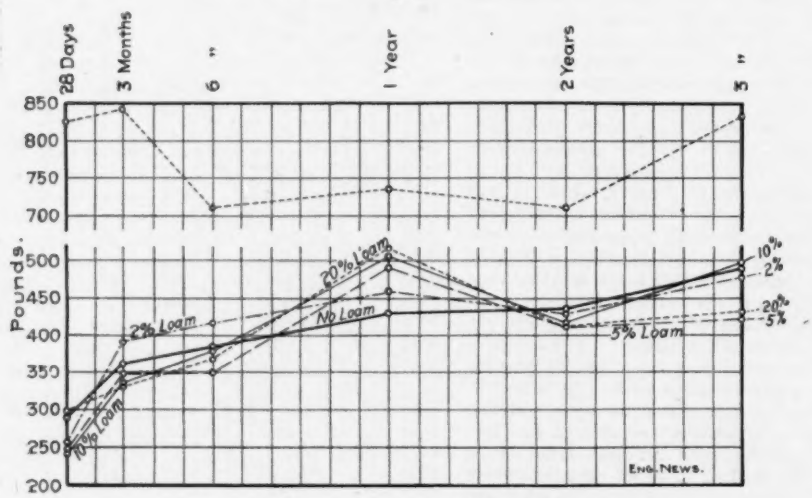


Fig. 2. Tests of 1 to 3 Mortar.

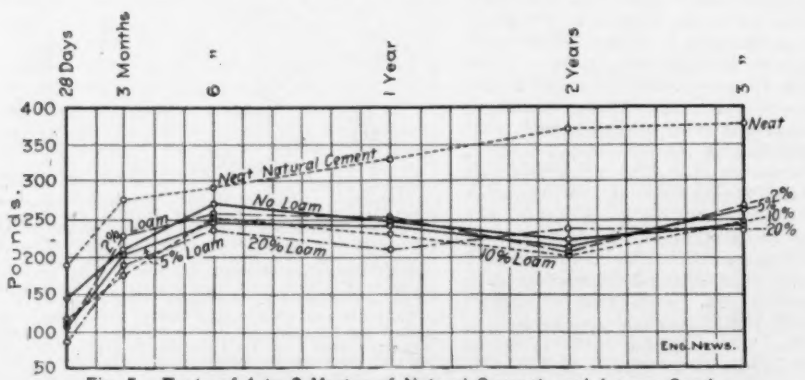


Fig. 5. Tests of 1 to 2 Mortar of Natural Cement and Loamy Sand.

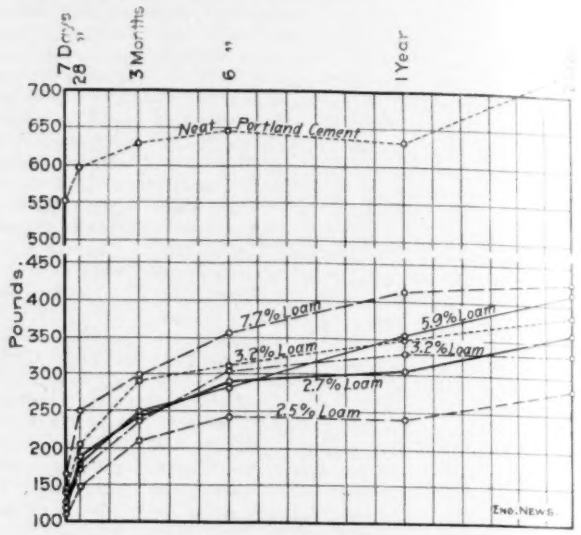


Fig. 3. Tests of 1 to 3 Mortar with Sand from Different Pits.

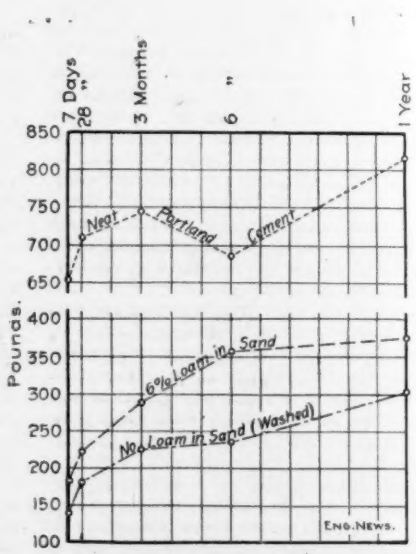


Fig. 4. Tests of 1 to 3 Mortar with 6% Loamy Sand with Same Sand Washed.

DIAGRAMS SHOWING TENSILE STRENGTH OF MORTARS MADE OF LOAMY SANDS.

Since the above was written the writer has read two comprehensive articles on momentum grades. The first of these is a paper by Mr. C. D. Purdon, Chief Engineer of the St. Louis & San Francisco Railroad, entitled "Reduction of Grade on Railroads." This paper was read May 6, 1903, before the Engineers' Club of St. Louis, and is published in the Journal of the Association of Engineering Societies, Vol. XXXI., No. [illegible]. The second is an article by Mr. J. B. Berry, Chief Engineer of the Union Pacific, on "Velocity [illegible]," and is embodied in Bulletin No. 49, May [illegible], 1904, of the American Railway Engineering and Maintenance of Way Association. Mr. Purdon's article consists of a somewhat general treatment of the subject, and Mr. Berry's article gives a practical application of Mr. Purdon's method to the reduction of grade on the Wyoming, or Rocky Mountain Division of the Union Pacific. The investigation undertaken was to show to what extent grades of as much as 79.2 feet to the mile and less could be operated at speeds of not less than ten miles an hour by a train loaded for all it could pull up a grade of 43.3 feet to the mile at a maintained speed of ten miles an hour.

There is no essential difference between Mr. Purdon's work and Mr. Dennis's. Mr. Purdon's results are probably safer because he does not assume the train resistance to remain constant as the speed increases. Possibly the use in these two articles of the train resistance formula found by Wellington from experiments on the light cars of two decades ago might be characterized as ultra-conservative. Though it might be equally true that Mr. Dennis's assumption that the train resistance is constant between speeds of 5 and 35 miles an hour is ultra-optimistic.

There is one clause in Mr. Purdon's article that

TABLE I.—Loamy Sand Tests in Pounds.

Test No.	Mortar.	Loam, %	Tensile strength in lbs. per sq. in. 28 days.	Months 3.	Months 6.	Years 1.	Years 2.	Years 3.
1012	Cement & sand, 1:2, by weight.	None.	503	523	546	563	612	705
1025		2	439	504	509	577	530	604
1028		5	356	445	454	549	485	551
1033		10	346	465	464	506	520	615
1037		20	344	368	418	522	422	432
1014	Cement & sand, 1:3, by weight.	None.	292	361	384	430	435	493
1027		2	257	390	418	458	431	479
1031		5	248	348	352	491	414	422
1035		10	242	335	379	506	417	499
1039		20	209	334	368	515	414	431
1022	Neat cement used (Portland)		825	841	712	735	713	834

might well be considered by every railroad engineer engaged in, or contemplating, grade reduction.

It seems reasonable in grade reductions to take account of the velocity with which a train reaches an adverse grade, calculate how far up that adverse grade the stored-up energy and capacity of the engine will take the train, and begin reduction at that point instead of at the foot of the hill.

Mr. Berry does not take so bold a stand on this point, and yet he says:

Where it is desired to reduce the ruling gradient, and the financial conditions are such as to limit the expenditure to the minimum amount possible to perform the work, the short stretches of heavier grade are permissible, as they may be brought to the ruling grade at a later period when conditions are more favorable.

In the writer's opinion it may now at last be said that a full exposition of the principles governing the use of momentum grades can be found written in current engineering literature.

LOAM AND CLAY IN SAND FOR CONCRETE.

By G. J. Griesenauer.*

In an article entitled "Location and Construction of the Ohio Residency; Pittsburg, Carnegie & Western R. R.," in Engineering News of May 21, 1903, on page 446, the following statement is made concerning loam in sand for concrete: "Laboratory tests have shown that by washing out the 10% of loam contained in the creek sand, the tensile strength of the mortar is reduced in a marked degree." In the issue of Engineering News of Nov. 19, 1903, is an article on "The Effect of Clay and Loam on Cement Mortar," by Prof. C. E. Sherman, Professor of Civil Engineering at Ohio State University, at Columbus, giving data and diagrams which indicate that the presence of either of these foreign materials increases the strength of sand for concrete purposes.

In the cement testing laboratory of the Bridge & Building Department of the Chicago, Milwaukee & St. Paul Ry., of which Mr. C. F. Loweth is Engineer and Superintendent, a variety of similar tests have been carried on under the direction of Mr. J. C. Hain, Engineer of Masonry Construction. The first experiment to determine the effect of clay in sand was made about four years ago, with sand from a Minnesota sand pit owned by this railway. Two classes of sand were obtained from it: fairly clean sand, and sand containing loam or clay. The clean sand contained about 1.5% foreign material, and the dirty sand from 5 to 8%. Comparative tests were made to determine whether it would be safe to use the dirty sand. Two mixtures (by weight) of cement and sand were made: a 1 to 2, and a 1 to 3 mixture of Portland cement with the clean and the dirty sands. The result of the 1 to 2 mortar shows a slight favor for the clean sand, while the 1 to 3 mortar shows the dirty sand to be superior.

These rather unlooked-for results led to making a series of tests in which clean sand was used, to which different percentages of loam were added. The loam was a rich surface soil. Mortars were made in proportion of 1 to 2 and of 1 to 3, of the same Portland cement as used in the above-mentioned tests, and a washed pit sand, to which were added different percentages of loam, ranging from

*Cement Tester, Bridge and Building Department, Chicago, Milwaukee & St. Paul Ry., Chicago, Ill.

TABLE III.—Comparative Tests of Loamy and Clean Sand (washed). Tensile Strength in Pounds.
Proportions: Cement and sand = 1:3 by volume.

Test No.	Mortar of cement and	Loam, %	Tensile strength in lbs. per sq. in. Days. 7.	Days. 28.	Mos. 3.	Mos. 6.	Year 1.
3215	Jackson sand ..	6	185	223	290	359	377
3252	Jackson sand ..	None.	140	181	227	235	303
3212	Neat cement used*		654	710	743	687	818

*Portland.

TABLE II.—Loamy Sand Tests in Pounds.

Test No.	1 to 3 mortar of cement and	Loam, %	Tensile strength in lbs. per sq. in. Days. 7.	Days. 28.	Mos. 3.	Mos. 6.	Yrs. 1.	Yrs. 2.
2040	Hammond sand.	2.7	119	191	243	288	303	360
2041	Rockton "	2.5	116	147	209	241	240	283
2042	Pound "	7.7	166	248	290	357	413	429
2043	Paint River "	3.2	146	206	293	312	351	383
2044	Eagle No. 1 "	3.2	128	185	239	302	328	332
2046	Eagle No. 2 "	5.9	140	188	249	281	354	415
2039	Neat cement used*		533	596	629	646	632	737

*Portland.

2% to 20%. The percentage of loam added was based on the weight of the sand and the weight of the loam. All materials were proportioned in the dry state. The tensile strength results of this series are tabulated in Table No. 1., and shown graphically in Figs. 1 and 2. In this series, as in the first tests, the 1 to 2 mortar favors the clean sand, while the 1 to 3 mortar, up to 10% loam in sand, shows equal to or better than the clean sand.

Table II., which is graphically shown in Fig. 3, gives tensile results in pounds, of sand from several of this railway's sand pits, containing in their natural state from 2.5% to 7.7% of loam and clay. These tests, which extended to two years (three-year test to be obtained), show results remarkably in favor of loamy sand. In this series of tests, which includes sand from several pits, it should be noted that the concrete made of the sand containing the least foreign substance, is the lowest in tensile strength, and that containing the most, the highest in tensile strength. Regarding these two sands it might be well to mention another point, namely, the 2.5% foreign substance contained in the "Rockton" (Ill.) sand was a rather mealy substance, and very different from the 7.7% foreign substance in the "Pound" (Wis.) sand which was of a plastic and putty-like nature. In other words, taking a handful of each of these sands in a damp state, and pressing it into a ball, the sand with the 7.7% foreign material in it would cling together with considerable adhesion, while that with the 2.5% was not of this nature.

Another set of tests, results of which are shown in Table III. and graphically represented in Fig. 4, were made of a sand containing naturally 6% of clay, and another, of the same sand after the clay had been carefully removed by washing. The results of these tests show the sand with the clay left in superior to the washed sand by an average of about 32.0%. A 1 to 3 mortar was also made, using natural cement instead of Portland cement. In this test, Table IV., which is graphically represented in Fig. 5, it will be noticed that the clean sand results are generally better than the loamy sand results.

The clay in the sand, as received from the pits, contains a different composition than does the surface soil, which was artificially added; and these tests indicate that the naturally dirty sand is affected more favorably by the foreign substance it contains than that where the loam was artificially mixed with it. This is probably because the foreign substance naturally in the sand is more nearly similar in its composition to sand, and more thoroughly assimilated, than is the surface soil, which was artificially mixed with the sand.

It therefore seems that it would be well, before rejecting a sand on account of the foreign material it contains, to make actual mortar tests of it as received from the pit or stream, and other similar tests after the foreign substance has been carefully removed by washing. These tests should be accompanied by a test of the standard sand used in the laboratory, to know, if an unwashed sand shows up better than washed sand, whether it is yet as good as the standard sand, and whether it is as good as it should be for the work it is intended for.

The above tests probably throw but little more new light on this subject than do those referred to in the beginning, but a record of them cannot fail to add to our present knowledge and convenience in this direction.

TABLE IV.—Loamy Sand Tests in Pounds.

Test No.	Mortar.	Loam, %	Tensile strength in lbs. per sq. in. 28 days.	Months 3.	Months 6.	Years 1.	Years 2.	Years 3.
1245	Cement & sand, 1:2, by weight.	None.	144	209	271	247	223	241
1237		2	113	231	258	251	203	266
1238		5	116	205	249	242	214	265
1239		10	117	177	252	232	202	244
1240		20	87	189	239	209	238	240
1157	Neat cem't used.*		189	275	292	331	371	379

*Natural cement.

SAND AND SCREENINGS FOR SIDEWALK CONCRETE.

Limestone screenings for concrete are being used in a number of cases in Chicago, including the masonry work of some of the new city bridges, but the use of screenings is not permitted by the city for use in sidewalks. This is due to the fact that they are not mentioned in the specifications forming part of the city ordinances governing sidewalk construction, and as the courts have held that the ordinances must be specific, an attempt has been made to revise the specifications. It was proposed to include screenings in the specifications of the Board of Local Improvements, but the proposition is reported to have been rejected for the following reasons: 1, That the color of the cement and screenings is so nearly alike that when a job is finished the inspectors cannot tell whether a sufficient quantity of cement has been used; 2, That in wet weather it is impossible to properly mix the screenings with the cement. The first objection seems to be of little weight, as an inspection that consists in judging of the quality of the concrete by its color in the finished work is not good for much; the second objection does not appear to be supported by practical experience. In reply to an enquiry concerning this matter, Mr. John Ericson, M. Am. Soc. C. E., Vice-President of the Board of Local Improvements, states his position in regard to this change as follows:

About two years ago a number of tests were made by Mr. P. C. McArdle, cement tester, Bureau of Engineering, under my direction. These tests were made with the view of comparing the relative strength of mortar made with limestone screenings, granite screenings and torpedo sand. The limestone screening briquettes showed remarkable strength; in fact, both the tensile and compressive strength were greater in the case of the limestone screening briquettes than in the case of those made with either granite screenings or torpedo sand. The screenings used were of the best quality. Since then I have seen records of tests tending to show that concrete made with limestone screenings loses its strength rapidly with age. Not being entirely satisfied as to the merits and uniformity of limestone screenings, and the advisability of their use in place of torpedo sand for concrete purposes, I have not advised the change.

As screenings have been used in concrete work in various parts of the country (including Chicago) with entirely satisfactory results, and as suitable sand is not always readily obtainable, while screenings are plentiful and often cheaper than sand, a new city ordinance with revised specifications permitting the use of either sand or screenings was drawn up. One objection made was that while concrete made with screenings might be adapted for general work it was not adapted for exposed work, and to quiet this objection the specifications were amended to require the ¾-in. finishing layer to be made with "torpedo gravel or granite screenings," the same as for concrete sidewalks in which sand is used. The ordinance was discussed in the Judiciary Committee, where several speakers favored the change and explained the general use of screenings in concrete, and on March 14 the ordinance was presented to the council, which passed it by a vote of 50 to 12. On March 23, however, the ordinance was vetoed by the mayor, who gave the following explanation of his action:

I am advised by the chief sidewalk inspector that the provision of this ordinance permitting the use of limestone screenings would result in the laying of imperfect cement sidewalks. He advises me that the specifications of the Board of Local Improvements exclude the use of limestone screenings and that from the information he has gathered, the reputable sidewalk layers of the city who desire to live up to their guarantees, would not care to lay cement sidewalks with limestone screenings.

As to the first objection made by the mayor, it must be noted that the inspector is not an engineer, and probably not very familiar with concrete work, and it seems to imply simply that contractors could and would more easily scamp their work if the use of screenings were permitted. As to the objection that reputable sidewalk layers would not care to use this material, it is to be noted that they are not compelled to use it; they have their choice of sand or screenings, and would probably use whichever was the cheaper. If the two kinds of concrete—properly made—will be equally good, and so satisfy the five-year guarantee, it does not matter to the contractor which

he uses, and he will be governed by market conditions.

We give below the new specifications as proposed and as adopted, the second paragraph (enclosed in parentheses) having been struck out.

CONCRETE MIXED WITH SAND.—The concrete shall consist of 1 part of cement equal in quality to the best Portland cement, 2½ parts of clean torpedo sand free from dust, loam and dirt, of sizes ranging from ¼-in. down to the finest, and 5 parts of crushed limestone, or other stone equally as good for concrete purposes, or washed gravel, all of which shall be free from dust and dirt or other foreign substances, and of sizes measuring not less than ¼-in. or more than 1 in. in any dimension. The cement and sand shall be thoroughly mixed dry, after which it shall be moistened with water and made into a stiff mortar. The crushed stone or gravel, after being sprinkled with water, shall then be incorporated in the mortar and the mass shall be thoroughly mixed together by turning over with shovels, hoes or mechanical mixers at least three times, and then placed on the foundation and rammed until perfectly solid.

(CONCRETE MIXED WITH LIMESTONE SCREENINGS.—The concrete shall consist of 1 part of cement equal in quality to the best Portland cement, 2 parts of clean limestone screenings, free from dust, loam or dirt, of sizes ranging from ¼-in. down to the finest, and 4 parts of crushed limestone or other stone equally as good for concrete purposes, or washed gravel, all of which shall be free from dust and dirt, or other foreign substances, and of sizes measuring not less than ¼-in. nor more than 1 in. in any dimension. The cement and screenings shall be thoroughly mixed dry, after which it shall be moistened with water and made into a stiff mortar. The crushed stone or gravel, after being sprinkled with water, shall then be incorporated in the mortar, and the mass shall be thoroughly mixed together by turning over with shovels, hoes or mechanical mixers at least three times and then placed on the foundation and rammed until perfectly solid.)

The second or finishing layer, ¾-in. thick, composed of 2 parts of cement equal in quality to the best Portland cement and 3 parts clean torpedo gravel or granite screenings, shall be put on before the first layer has set, and trowelled sufficiently to give the completed walk a smooth, even and glossy surface.

The satisfactory quality of concrete made with screenings for the Jerome Park Reservoir, New York, was discussed in our issue of Nov. 19, 1903, while the economic aspect of the use of screenings was discussed in our Construction News supplement of Oct. 8, 1903. The results of comparative tests of briquettes made with sand and with screenings were given in our issues of April 2 (U. S. Engineer corps) and April 16, 1903 (C. M. & St. P. Ry.); both of these were in favor of the screenings, and the latter especially showed very much higher results for limestone screenings than for sand or gravel.

One provision of the specifications that seems to call for criticism is that which requires a "glossy" finish, and it is this which is probably responsible for the slippery character of many concrete sidewalks when wet. A much better finish is that which gives a roughened sandy surface, a good example of which is afforded by the broad concrete sidewalk around the new Chicago post-office.

STUDIES OF COLOR IN WATER; METROPOLITAN WATER SUPPLY, MASSACHUSETTS.

By Ernest G. Hopson,* C. E.

Among other important phases of the study of improvement in quality of public water supplies, an increasing amount of attention is being given to the matter of color. It has been found that color having been acquired by a surface water is extremely difficult to eliminate and cannot be ignored; a water that may be of exceptionally good quality and eminently desirable for a public supply in other respects may be rejected for the reasons of high color alone, preference being given to more attractive waters even when more difficult and costly to obtain; and many otherwise good waters at present used by the public have become extremely unpopular mainly on account of their high color.

Color is present in practically all surface waters to a greater or lesser extent, and is generally acquired by contact with decaying vegetable tissues. The color is a dye, mostly in solution, in contrast with turbidity, which consists of particles in suspension. The problem of reducing the colors of public supplies has by no means been neglected by engineers during the past, but the difficulties in the way of removing or even appreciably reducing the tint have been so great that in general nothing more has been done to effect decolorization than ordinary sand filtration, or bleaching in large storage reservoirs.

The ordinary method of slow sand filtration does not in general afford a satisfactory remedy for highly colored waters, when operated at the rates that are practicable in public works on a large scale. It is usually found that with new sand a filter will for a few days entirely decolorize the water, but very soon color will begin to appear in the filtrate and gradually increase until it reaches about two-thirds the color of the applied water, after which it will remain about constant. These figures are only roughly approximated and apply to waters of an originally high tint, but they are sufficiently precise for practical purposes. Double sand filtration with intermediate aeration has been found to make a very large permanent reduction in color, but this process is expensive and sometimes impracticable.

The use of alumina either as a coagulent or as a filtering medium is perhaps the most effective way of decolorizing on a large scale, but this agent has many and obvious objections. Bleaching, or exposure of the water in its natural state to the action of light and air in large storage reservoirs, which is perhaps the only practicable means in common use for color reduction, will, if carried to sufficient length, cause an entire reduction. This action may be observed to advantage in large natural lakes that are fed by highly colored surface streams, where it will be often noticed that the effluent waters from the lake are very low in color or practically colorless whenever the lake is of large size in proportion to its drainage area. A well-known example is Lake Cochituate, a portion of the supply system of Boston and vicinity, that receives the highly colored waters of Beaver Dam Brook and other streams and yet yields a supply comparatively low in color.

The effect of storage in reducing color under conditions generally met with in artificial reservoirs is well illustrated by the Ashland Reservoir in Massachusetts. This reservoir has a capacity of about 1,500,000,000 gallons and a drainage area of perhaps six or seven square miles; the soil has been entirely removed from the bottom and there is a good depth of water in all parts of the reservoir. The size of the reservoir is such that the influent waters take almost an entire season, in ordinary years, to pass to the outlet gates; the average influent color for a number of years was estimated to be 96 and the average effluent about 56. The effect of bleaching in this reservoir thus shows a reduction of about 40%, an appreciable amount, certainly, but not sufficient to render the effluent entirely satisfactory. This reservoir, or a number of years was considered to be one of the best supplies for the city of Boston, and the conclusions reached from the above figures are that storage alone on any practicable basis is insufficient to reduce a highly colored water to the desired condition of limpidity. The principle that color in surface waters is the result of swamp contamination has been generally accepted and is unquestionable, but the assumption has been generally made that it is unavoidable.

The Metropolitan Water and Sewerage Board of Masachusetts has, during recent years, taken steps to lessen the color contamination of the Sudbury and Nashua supplies, and has inaugurated systems of drainage in several bad swamps on those watersheds. So far as known to the writer this board is the only public body that has attempted anything in the direction of color prevention.

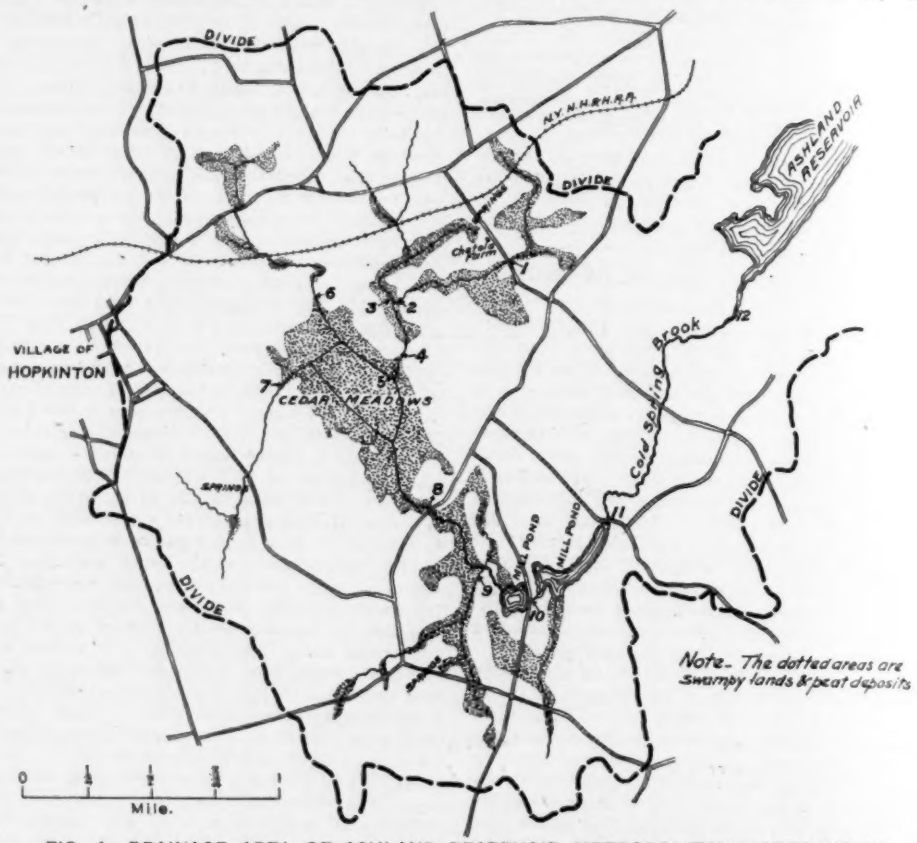


FIG. 1. DRAINAGE AREA OF ASHLAND RESERVOIR, METROPOLITAN WATER-WORKS, MASSACHUSETTS.

(The dotted areas indicate swamp lands and peat deposits. The numbers designate the location of points where color samples were taken.)

A number of shallow ditches have been cut in these swamps, and the surface waters that formerly flooded them have been to a large extent collected, and carried directly to the main channels. It would be interesting to know what have been the benefits derived from this drainage and whether it is considered to be sufficient for the purpose.

Several years ago the writer was engaged by the Water-Works Department of Boston to examine in detail the exact causes of color contamination of the streams feeding the Ashland Reservoir,* with a view to subsequent works to improve the water shed if such should be found feasible or desirable. The drainage area of the Ashland Reservoir was selected for this examination as being typical to a great extent of the entire Sudbury Watershed and not as presenting any especial features.

It was, of course, recognized in a general way before the examination was made that the

*3 Beach Terrace, E. 143d St., New York City.

*This was before the sources of the water supply of Boston were taken over by the Metropolitan Water Board, now the Metropolitan Water and Sewerage Board.—Ed.

swamps on the drainage area were the cause of the water discoloration, but no attempt had been made previously to examine in detail and precisely locate the sources of offence.

The drainage area of this reservoir, with its tributary streams and swamps, is shown by Fig. 1. Twelve points were selected, as shown by the numbers on the map, at intervals on the main stream and at important junctions of the feeders, and color observations were made with great frequency at these points during the spring of 1895. Samples were often collected daily, or as frequently as it was practicable to cover the ground, and a continuous record of all changes of color in the brooks at the several points was made from May 24 to June 29. On both of these dates heavy and prolonged rainstorms occurred and the flows of all the streams were large, the swamps being generally overflowed; the period intervening between these dates was exceptionally dry.

Color in the main stream was found to be highest during heavy flows and lightest during minimum flows. Fig. 2 shows in detail the curves of color plotted from the observations. The platinum-cobalt standard was used and readings were taken by means of a colorimeter, the invention of Dr. G. C. Whipple and Mr. W. E. Foss.

A study of the curves on this diagram is instructive; it will be noticed first, that Points 8, 10, 11 and 12, which are on the same stream, exhibit colors gradually becoming lighter as the volume of flow diminished, with a sudden recovery of the original high colors during the freshet of June 29. The volume of flow when the colors at these points were at a minimum just prior to June 29, was extremely light, many of the feeders being entirely dry and the bulk of the water flowing being contributed by the large springs in the watershed, shown by Fig. 1. The total volume yielded by the brook during May 24 and the few days succeeding was much greater than the volume yielded during the whole period following, up to June 29, and hence it may be noted that the average color of a brook is much more nearly represented by a sample taken during a period of high flow than one taken during low flow. It will also be noticed that the average color at Point 12 was invariably less than that at Point 11, and 11 less than 10, and the color at 10 less than that at 8, showing that the contributions of the drainage area below Point 8 were of an average lighter color than those above and that the main source of color would be found above that point.

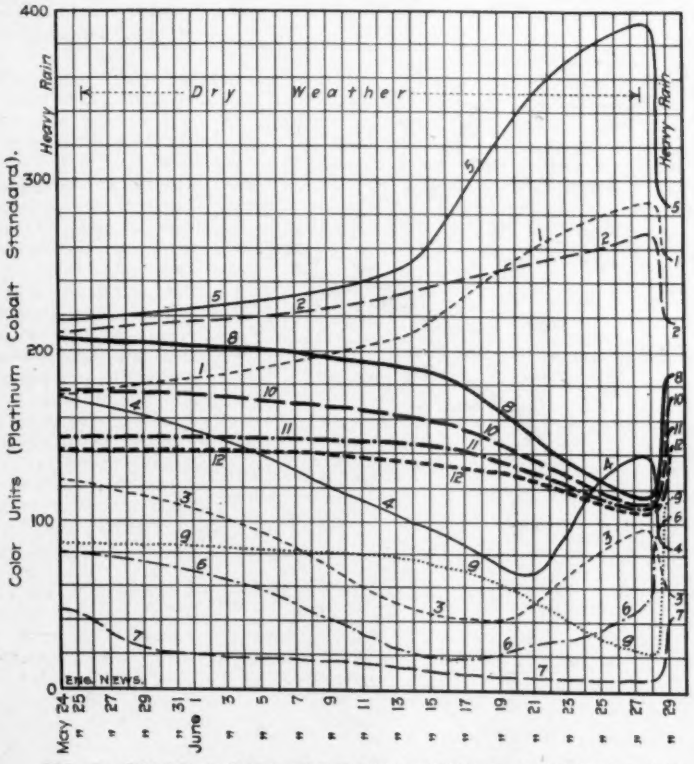


FIG. 2. COLOR CURVES FOR DAILY SAMPLES OF WATER FROM FEEDERS OF ASHLAND RESERVOIR.

Immediately above Point 8 there is a large tract of level peat lands called Cedar Meadows, where the three main feeders of the brook unite. Samples were taken at three points where these feeders enter the flat lands, numbered respectively 4, 6 and 7.

It will be observed that the colors at Point 7 were always very low; as a matter of fact the swamp contamination on this brook is almost inappreciable. The colors at Point 6 were always higher that at 7, and it was found that there were several large swamps along the course of this brook; but the color at Point 4 was considerably higher at all times than at either of the other two points, and the extent and quality of the swamp pollution on this stream was much greater than on the others.

The average color at Point 4 was, however, much less than at Point 8 on the main stream, and the average colors of the three feeders which would probably approximate an arithmetical mean of curves 4, 6 and 7 (the volume of flow of each feeder does not widely differ) was only a fraction of the average color at 8.

It was then evident that waters that entered Cedar Meadows at a comparatively low average color, issued therefrom with their conditions appreciably altered and of a high tint.

It should be recognized that all of the color of a brook water is not due to the influence of swamps alone. The colors at Point 7, the drainage area of which is almost free from swampy land, and where the brook is to a large extent fed by unusually large springs with absolutely colorless water, show a measurable amount; and other small brooks whose courses were almost free from swampy lands, but which were not so largely diluted with pure spring water as the brook at Point 7, show distinct color. The conclusions reached by the writer were that the average color of surface water, even where free from swamp discoloration, would in this drainage area not fall to less than about 40 color units, which would be due to contact with decaying leaves and fibers in the woods and fields and the muddy bottoms and sides of the brook channels. The small amount of color thus taken up through these latter causes I will style "normal color."

By reference to the color curves shown by Fig. 2 it will be seen that the average color of the three feeders above Points 4, 6 and 7 was about 100 units, or somewhat less, after making allowance for the high color prevailing during the period of heavy flows immediately succeeding to May 24. Of this amount 40 is approximately the normal color, and the balance, or about 60 units, is due to the influence of swamps above Points 4 and 6, but especially above Point 4. The average color at Point 8 will be seen to be about 200 units, of which 200 — 40 or 160 is probably due to swamps above this point. By this method of analysis it will be seen that roughly the influence of the swamps on the drainage area had increased the color at Point 8 from 60 to 160 color units during the passage through Cedar Meadows, or an increase of 167%. Hence it was evident that the main source of the high color lay in these peat lands.

Fig. 3 is a plan of these lands, showing on a large scale the edge of the peat area and the various brook channels and ditches therein. The area is some 120 or 130 acres, and the peat, as determined by numerous rod soundings, averages about 2½ ft. in depth, although in certain pockets it much exceeds this depth. Below the peat are generally found fine sands, sometimes quicksand, and occasionally hardpan. The ground water in the sands below the peat is free from color. At some period, probably not very remote, this area undoubtedly was a shallow lake which has been gradually filled in by accumulations of vegetation, the basis of the present peat formation.

At a large number of points in this area holes were dug in the peat and the nature of the material examined at different depths; it was found in general that the peat near the surface was of a browner tint than that below, which was almost black in color, and that the surface peat was also more fibrous, of looser texture and more porous than the deeper material. The water in the upper layers apparently had comparatively a free and unobstructed opportunity to percolate, as compared to that in the darker colored and more compact layers, deeper down. No doubt the action of frost in loosening the upper layer of the material is primarily the cause of the differences noted.

Samples of water taken from holes in the peat showed a very high degree of color; in some places this color was as high as 1,450, but the general average was between 400 and 700. The appearance of the higher colored samples may be compared to that of rum in depth of tint and absence of turbidity. It was observed that in places where the peat was more compact and less fibrous the samples were of a lighter color than where the reverse occurred. The highest colored samples of water were taken from the peat in shallow holes of not more than a foot in depth where the peat was dark brown in tint and extremely fibrous and porous in structure. It would appear that the surface layer exposed to the disintegrating action of the elements and continual changes from a wet to a dry condition is in a state of decomposition to which the lower layers are not subject and that the dark brown dye communicated to the contained water is a product of this decay.

It will be noted that this area is by no means a swamp in a state of nature; a fairly satisfactory system of drainage was constructed during the seventies, two main channels being dug on each side of the area with cross ditches at intervals. The main channels are 2 or 3 ft. deep and perhaps 6 or 7 ft. wide and were laid to grade by an engineer; but duing the course of years have become much obstructed by vegetation of all kinds, and their hydraulic efficiency has been seriously impaired. In spite of this fact, however, the general appearance of the tract is that of land in fairly dry condition, excepting immediately after heavy rains. I mention these facts to call attention to the inadequacy of a system of drainage suitable perhaps for agricultural purposes to cope with the problem of color prevention.

A detailed examination was made of the waters in the main channels and cross ditches, and the results of a series of samples collected on one day, June 16, are shown on the map, Fig. 3, by the figures representing the colors at the several points indicated. It will be noted that the waters in the cross ditches were much higher colored than those in the main channels; the ditch water at the time of collection was in appearance stagnant and foul, and no perceptible current could be detected flowing from the ditches into the main channels, but that there was such a flow was evident from the higher colors in the main channels immediately below the junctions with the ditches than the colors immediately above the junctions. As before stated the colors in the side ditches were exceedingly high and consisted almost wholly of leachings from the spongy peat adjacent, the high color of which has already been alluded to.

In certain parts of the area where the drainage system was imperfect the surface was partially flooded at times, tussocks of swamp grass standing out of pools of stagnant water, but these places were only local. This stagnant water would after long exposure become foul and high colored, but in general it was noted that this surface water seldom directly communicated with the brooks and had but little influence on the general color of the latter. Surface water of this descrip-

tion, as a rule, was found to lie in isolated pools that gradually disappeared by evaporation or the lowering of the ground water during dry periods. During heavy rains, however, when the surfaces of the swamps were flooded, the contents of these stagnant pools were washed into the main channels and helped to create the sudden rise in color that accompanied the beginning of the high flows, but it is evident that the effects of these washings could be but of a very temporary nature.

A study of all these causes and effects leads to the strong conclusion that the great bulk of the color yielded by a peat area such as this is derived from leachings from the upper 12 or 18 ins. of the peat and that this highly colored solution enters the sides of the ditches and drainage channels below the surface of the ground.

The conditions that give rise to and maintain the high color of the water at Point 8 may be described as follows: A rainstorm occurs and the run-off is rapidly shed from the steep and impervious uplands into the basin formed by the Cedar Meadows area. The main channels here being badly choked by weeds and bushes are unable to discharge the volume delivered into them and rapidly fill up and overflow the meadows. By this means the stagnant pools on the surface in places and all the highly colored waters in the cross ditches are thoroughly flushed and the color of the brooks at once jumps to a high point. At the cessation of the rainstorm the channels begin to catch up with the flow of the stream and the process of lowering the level of the water in the mass of spongy peat to its original level begins. This process, as before described, is accompanied by continuous high-colored leachings into the brook channel, thus maintaining the high color of the brook waters, and is only terminated when the next rainstorm occurs and the level of the water is again raised, the process being renewed. It would be a safe guess to make that 90% of the color from swamp pollution is effected by this means.

That some little addition to color takes place through contact of flowing water with the muddy bottoms and sides of brook channels is probable, but that it is but slight is undoubted, as proved by tests made by shaking up samples of very foul mud with distilled water, and observing the color in the product after sedimentation; the amount of color taken up by this means was found to be almost imperceptible.

The impression that appears to be general among water-works engineers who have given the subject any attention is that the mere cutting of ditches to remove the accumulations of stagnant water from the surfaces of swamps is the correct action to effect a radical improvement in the color of the adjacent brooks. While there is no doubt that the elimination of foul surface water is decidedly beneficial, I doubt that the advantages secured by this means are more than a check on the rapid rise in color after heavy rains. In the case of Cedar Meadows we have an area that is already intersected with wide channels and whose surface is generally dry, and that yet is a most active agent in producing color in the water of Cold Spring Brook. The problem to be solved in cases of this kind is to attack the true seat of the evil, and that will only be accomplished by preventing the present continual changes of level of water in the upper layers of the peat. To effect this end I would suggest that channels located around the margins of the swamp be constructed, these channels acting as interceptors and diverting all drainage from the uplands from entering the swamp itself. The depth and capacity of these channels should be such that the surface of the flowing water will be a little below the level of the bottom of the layer of peat which it is proposed to keep free from saturation. If it be assumed that the upper 18 ins. of peat be the chief colorizing agent to be protected against, I would propose that the intercepting channels be designed to carry flood flows of not less than 1 in. on the drainage area per day below a level of not less than 2 ft. from the surface of the meadows. This would not call for any extravagant construction and could probably be accomplished by channels not deeper than 4½ to 5 ft.. With this method of construction the changes in level of the ground water in the peat would be confined to the deeper laying material, from which danger is not to be expected, and the only water coming into contact with the upper layer of peat would be the rainfall on its surface.

Flood flows greater than a watershed inch are not frequently experienced, and it will probably not be found practicable to provide for greater quantities than this in the channels without an undue expense.

Following up the brook that enters Cedar Meadows at Point 4, it will be noticed that the brook divides into two branches, and that color observations were taken on each branch immediately above the junction. The average color at Point 3 was considerably less than Point 4, and that at Point 2 much higher than at Point 4. Thus the bulk of the coloring matter at Point 4 was derived from sources above Point 2.

The observations taken at Point 1 on the same brook as Point 2, but some distance above it, show a close agreement on the whole with those at Point 2, and indicate that the relative swamp contamination above and below Point 1 are about the same. This was borne out by an examination of the ground that disclosed one bad swamp above and one below this point. The color curves at Points 1 and 2 show a steady increase in color during the period of examination; the actual flow of water in this brook was, however, very small towards the end of the period when the color was highest and consisted almost wholly of the leachings from the peat in these two swamps. There is no question but that the lowering of the water level in these two swamps would effect a very material improvement in the color of the water at Point 4.

In studying out details of small drainage areas and streams it will be noted that the ordinary flow of a small stream is often by no means proportional to its visible drainage area; the influence of large springs materially modifies any conclusion that may be made as to the yield of the stream, that are based on drainage area and rainfall. During and after heavy rains the flow of small brooks more nearly approximates the amounts proportionate to their visible watersheds, but after a period of dry weather the yields of many streams of relatively large drainage area will be found much less than those of smaller areas, that contain larger springs than the former. The influence of large springs tends to equalize the flow of small streams to a material extent by their almost constant supply, and to keep the average color of the yield down to a low point. This will be noted by reference to the color curves at Points 3, 4, 7 and 9; at these points the streams flow consisted almost wholly of water issuing from the large springs noted on the map, Fig. 1, during the dry period between May 24 and June 29. The influence of swamp drainings at no time excessive, excepting in the case of No. 4, rapidly lessened as the swamps dried up and about the middle of June the colors of all of them became very light, while the yield remained substantial. In the cases of Points 3 and 4 the colors began to increase after June 20 on account of the failure of the spring near Chetola Farm about that time.

Curves 1, 2 and 5 (Fig. 2) showed a steady increase of color at these points during the same period, which may be explained by the fact that there are no large spring supplies on these streams; the yield became extremely small, and towards the latter end of the period when the colors were at the maximum was insignificant, consisting wholly of the last drawings from the peat beds.

To sum up certain conclusions that were drawn by the writer, it may be said that: A brook whose color is increased temporarily to a high point during and after rains, but which in general flows of a light color, shows indications of pollution from the flushing of stagnant surface pools in swampy lands, and a remedy for the temporary high color may probably be found by the construction of shallow channels to prevent the accumulation of such surface water.

A brook that steadily maintains a high degree of color for long periods, gives sure proof of the accession of leachings from peat beds and the remedy may only be found by a system of deep drainage such as described.

A brook whose color is generally very low excepting during or immediately after rains (such as No. 7) shows an almost entire freedom from swamp pollution with the exception of surface washings, which are unavoidable.

Finally, I would state that in a number of cases of a highly colored supply it will be found to be a good investment carefully to study the exact cause of the evil with a view to effecting a remedy if such may be accomplished at reasonable cost. The probability is that in a majority of cases it will be found that the trouble is caused by certain isolated localities where the expense of ditching and draining would not be excessive, and the resulting benefits well worth the outlay.

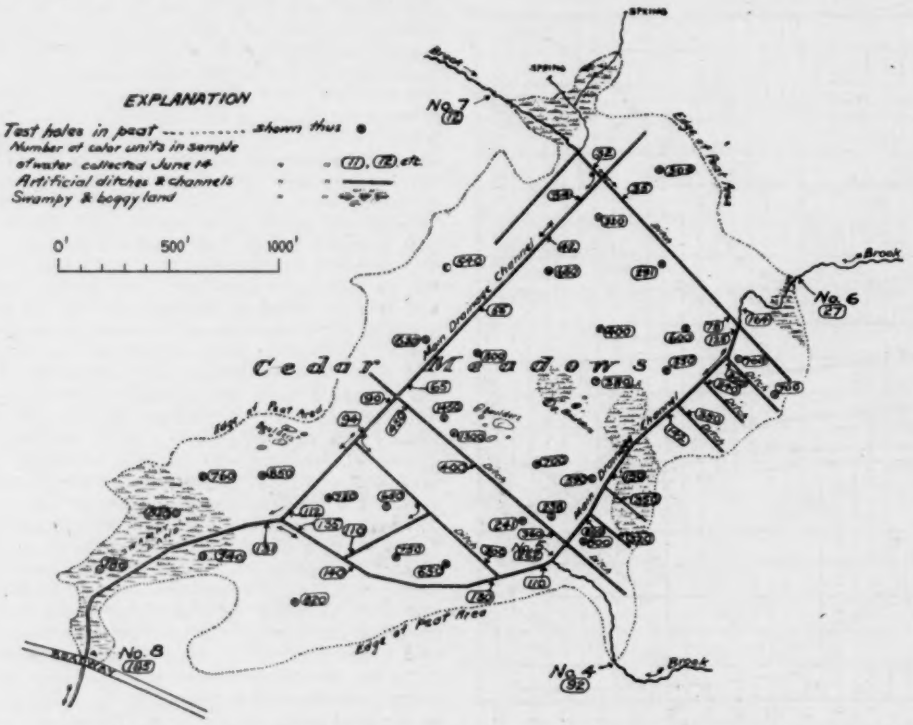
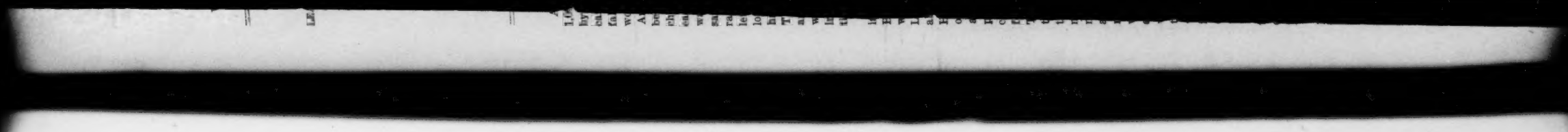


FIG. 3. ENLARGED PLAN OF CEDAR MEADOW, DRAINAGE AREA OF ASHLAND RESERVOIR.

(Nos. 4, 6, 7 and 8 correspond to the color sample paints indicated on Fig. 1.)